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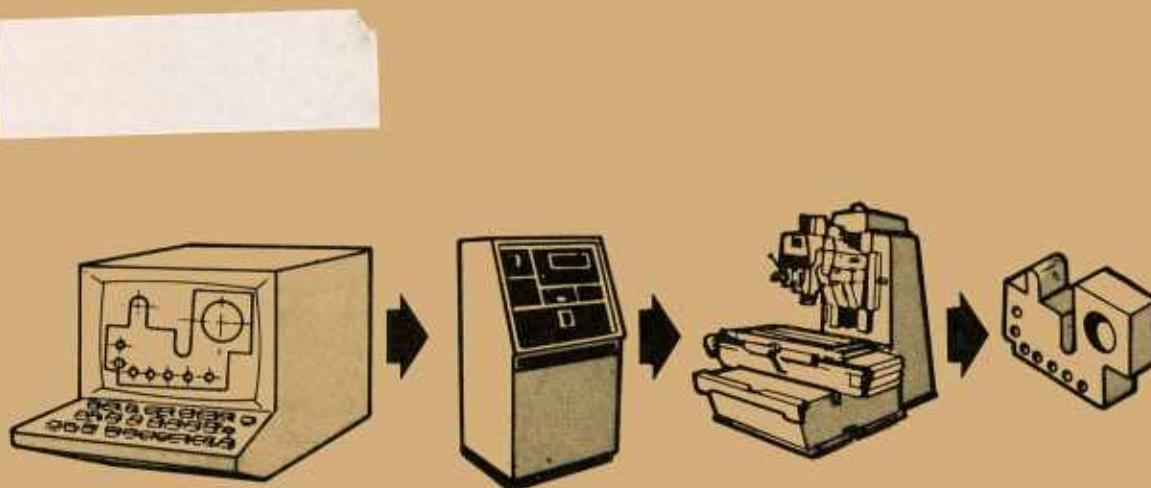
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CAM HIGHLIGHTS

(FY 82)

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PREPARED BY

OCTOBER 1982

USA INDUSTRIAL BASE ENGINEERING ACTIVITY

MANUFACTURING TECHNOLOGY DIVISION

ROCK ISLAND, ILLINOIS 61299

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. The summaries highlight the integration of computers in manufacturing and are organized into eleven sections for this document. These eleven sections correspond to system technology areas which are listed with their numerical classification number.

TECHNOLOGY
AREA NUMBER

TECHNOLOGY AREA TITLE

100	Architecture
200	Fabrication
300	Data Base/Data Automation
400	CAD/CAM Interaction
500	Planning and Group Technology
600	Manufacturing Control
700	Assembly
800	Simulation, Modeling and Operations Research
900	Materials Handling and Storage
1000	Test, Inspection and Evaluation
1100	Continuous Flow Processes

Applications for the control systems covered by the summaries include: optical machining, computerized process planning, voice controlled NC tape preparations and updates of some previously published CAM articles.



DEPARTMENT OF THE ARMY
US ARMY INDUSTRIAL BASE ENGINEERING ACTIVITY
ROCK ISLAND, ILLINOIS 61299

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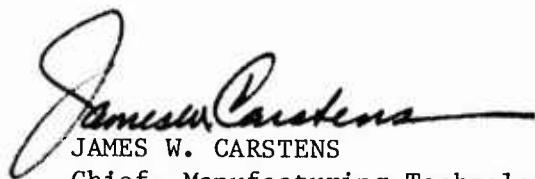
DRXIB-MT

SUBJECT: Computer Aided Manufacturing (CAM) Highlights

SEE DISTRIBUTION

1. Reference DARCOM-R 15-13, "DARCOM Computer Aided Manufacturing (CAM) Steering Group," dated 3 June 1977.
2. The CAM Highlights presents summaries of 39 Army CAM efforts that are either completed or on-going. The Army Procurement Appropriations funded these efforts through manufacturing technology, facilities, or major systems contracts. The document was prepared under the auspices of DARCOM-R 15-13, and represents a compilation of efforts up to October 1982. Information presented was obtained from various management documents submitted to IBEA during the life cycle of the efforts and through follow-up material supplied by the program proponents.
3. Comments on this material may be sent to Mr. T. Locke, US Army Industrial Base Engineering Activity, DRXIB-MT, Rock Island, IL, 61299. Additional copies may be obtained by written request to the Defense Technical Information Center, Attn: TSR-I, Cameron Station, Alexandria, VA, 22314.

FOR THE DIRECTOR:



JAMES W. CARSTENS
Chief, Manufacturing Technology Division

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SUMMARY

The CAM Highlights describes Army efforts using Computer Aided Manufacturing (CAM) to upgrade its industrial base. Improvements in productivity and quality of products were obtained through the integration of computers in manufacturing. This document provides information describing efforts and points of contact for additional information.

Some efforts were initiated with Manufacturing Methods and Technology (MMT) projects and have follow-on Provision of Industrial Facility (PIF) for implementation, while still other efforts are implemented under major systems contracts either separately or in conjunction with other MMT or PIF projects. All efforts presented were funded by the Army Procurement Appropriation and are representative of efforts pursued through the Army CAM program.

The efforts described highlight the integration of computers in manufacturing and are organized into eleven sections for this document. These eleven sections correspond to system technology areas which are listed in Exhibit 1 with their numerical classification number, along with the number of efforts presented in each area.

EXHIBIT I SUMMARY OF CAM HIGHLIGHTS

<u>Technology Area Number</u>	Number of CAM Efforts		<u>Technology Area Title</u>
	<u>MMT</u>	<u>PIF</u>	
100	2	2	Architecture
200	2	3	Fabrication
300	2		Data Base/Data Automation
400	2		CAD/CAM Interaction
500	4		Planning & Group Tech
600	5	1	Manufacturing Control
700	1	1	Assembly
800	2		Sim,Model & Opr Resch
900		1	Mat Handling & Storage
1000	10		Test, Inspection & Eval
1100	1		Continuous Flow Process
TOTAL	31	8	

The technology areas where the largest number of efforts have been presented are 200 - fabrication, 600 - manufacturing, 1000 - Test, Inspection, Evaluation.

Cost savings and productivity measures were difficult to obtain but are included where they are verifiable. Quantitative and qualitative benefits are being addressed in follow-on Effectiveness Reports published annually.

Efforts are presented in summary format, and cover a variety of CAM applications. Summaries of the 38 Army CAM efforts represent either completed or on-going efforts. CAM efforts were funded by manufacturing technology, facilities or major systems contracts. Application for the computer controlled systems addressed in these summaries include: optical machining, computerized process planning, voice controlled NC tape preparation and updates of some previously published CAM articles.

In maintaining inventories, Numerical Control (NC) machine tools are usually identified separate from the computer, controllers and software that support them. However, it should be understood that NC machines make a significant contribution to the production capacity of the Army's industrial base and represent a sizable dollar investment. The Army's NC inventory consists of 714 machines having an acquisition cost of \$157 million. A summary of an NC study conducted by the Industrial Base Engineering Activity is included as an appendix. A summary of the DARCOM main frame and microcomputer CAD/CAM capabilities is also listed.

INTRODUCTION

The United States has been experiencing a slow-down in the rate of productivity growth for several years. As a result, foreign products have become more competitive in markets that were previously dominated by the US. In order to retain an edge in the markets, the US has concentrated on introducing new technology.

One area of heavy technology involvement has been in applying computers to the work place. Within the last two decades, the Army has made significant advances in Computer Aided Design (CAD). The Army has also applied CAM to major combat vehicle programs and continuous flow chemical processes. This document describes some of the efforts made by the Army in recent years.

Eleven technology areas are used to classify, describe, and analyze CAM efforts in this report. Each effort has been categorized into one of the following technology areas. These areas were originally identified in the Air Force Integrated Computer Aided Manufacturing (ICAM) Program. Refinements were included by the Manufacturing Technology Advisory Group (MTAG) CAD/CAM subcommittee. Utilizing these CAM technology areas provides a structure for directing thinking toward an integrated systems approach. These technology areas and are defined as follows:

100 ARCHITECTURE

The purpose of the manufacturing architecture is to provide a clear understanding of the manufacturing environment and the interrelationships between subsystems that exist today. The manufacturing architecture, or framework, provides a common baseline in building integrated manufacturing systems.

200 FABRICATION

The fabrication technology area serves as a focus for all other technology area activities. Projects categorized into this area are directed toward increasing the productivity of manufacturing by systematically applying computer technology to all functions which directly and indirectly participate in fabricating parts.

300 DATA BASE/DATA AUTOMATION

The thrust area of data base and data automation is for technology required to support integration of the many stages and disciplines of manufacturing.

400 CAD/CAM INTERACTION

The purpose of this technology thrust area is to establish subsystems and procedures which will integrate the efforts of product design and manufacturing. The underlying concept is that of a common data base between engineering and manufacturing.

500 PLANNING AND GROUP TECHNOLOGY

This thrust area is for technology directed at optimizing process planning, production scheduling and control, factory layout and other tasks normally performed by indirect personnel that have a significant impact on manufacturing cost.

600 MANUFACTURING CONTROL

Manufacturing control is a thrust area providing generic technology for producing management oriented information tools for scheduling, monitoring and controlling operations within the manufacturing environment. This thrust area is closely related to the fabrication and planning and group technology areas.

700 ASSEMBLY

The assembly thrust area provides the integration of computer aided technology into assembly operations.

800 SIMULATION, MODELING AND OPERATIONS RESEARCH

This thrust area is soft technology for optimizing manufacturing systems through the application of operations research techniques.

900 MATERIALS HANDLING AND STORAGE

The integration of computer aided technology to support material handling is the primary goal of this thrust area. Objectives here include complying with OSHA and EPA standards and reducing costs and materials handling time through automated material storage, handling, and retrieval systems.

1000 TEST, INSPECTION AND EVALUATION

This thrust area emphasizes the development and transitioning of real time, computerized, nondestructive testing techniques for use in fabrication and assembly operations. Emphasis is put on automatic, in-process inspection and decision making without human intervention.

1100 CONTINUOUS FLOW PROCESSES

This technology area addresses the range of manufacturing processes that, for the most part, is continuous with minimum human interaction.

HIGHLIGHTS

100 ARCHITECTURE

REARM - Rock Island Arsenal

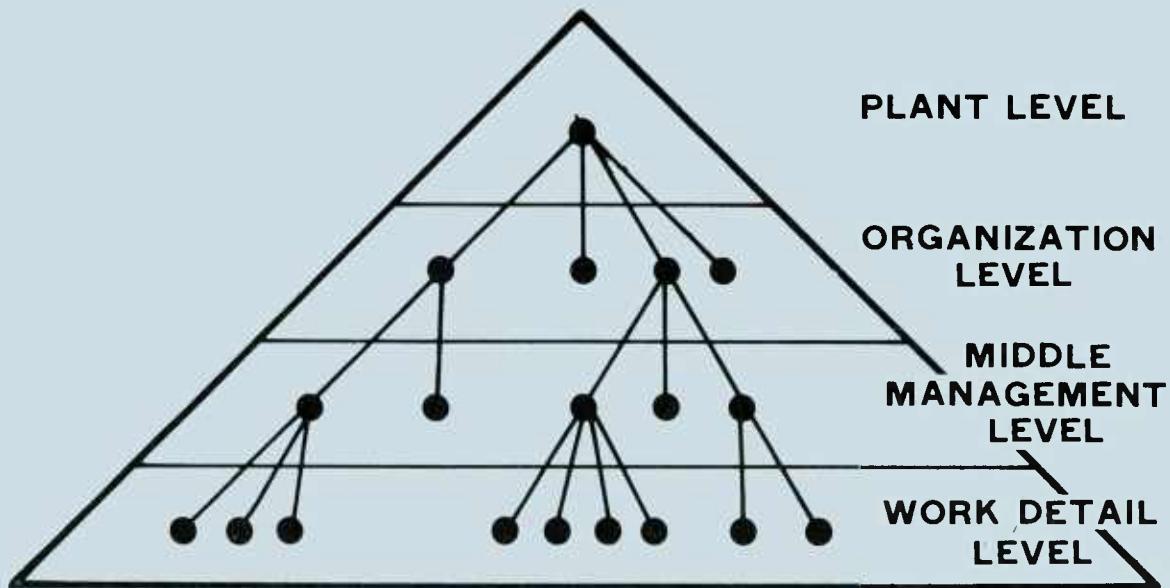
REARM - Watervliet Arsenal

- o FMS
- o DNC

HYBRID INTEGRATED COMPUTER AIDED DESIGN & MANUFACTURE

ELECTRONIC COMPUTER AIDED MANUFACTURING

100 ARCHITECTURE



To clearly define the purpose of manufacturing architecture, the theory is to provide a clear understanding of the manufacturing environment and the interrelationships between subsystems that exist today. The manufacturing architecture, or framework provides a common baseline upon which integrated manufacturing systems can be built.

The architecture provides an installation, a plant, or management level, a framework into which individual modules of CAM accomplishments will be integrated for total disciplined manufacturing operation and control. An example of the framework is illustrated for several levels of the manufacturing operation in the above figure.

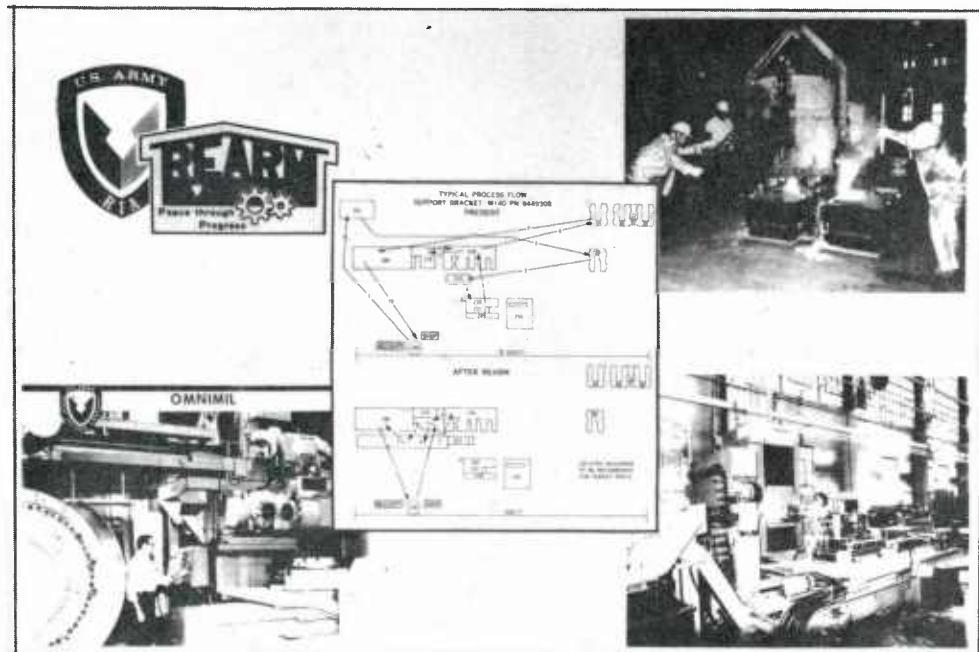
The integration of all levels of CAM from the work detailed level to the top management or facilities level is not an easy task to accomplish. Total integration requires persistent visualization of each subsystem into a hierachial framework of all subsystems.

REARM - ROCK ISLAND ARSENAL

The Rock Island Arsenal (RIA) has the mission to produce gun mounts, recoil mechanisms, artillery, gun carriages, machine guns, and related spare parts. During both peacetime and mobilization, this facility is required to retain an industrial base capable of producing these items.

The Arsenal is a unique GOGO manufacturing installation with a wide range of processes which include casting, metal cutting, closed die forging, heat treating and welding, surface finishing, final assembly and testing of complex parts. In the metal cutting process, the Arsenal operates equipment ranging from simple engine lathes to complex numerically-controlled machining centers.

The age of industrial plant equipment, including 2,308 DIPEC-reportable items at the Arsenal, averages 28 years. To rectify existing problems, the Arsenal developed a modernization program, "REnovation of ARmament Manufacturing (REARM)." REARM is a two-fold project for new construction and equipment modernization. Construction is planned during FY83-86 with coordinated equipment modernization in FY 82-87. This will be an extension of project REARM initiated at Watervliet Arsenal in 1979. The collage below shows the areas that REARM will improve.



A result of the RIA REARM program will be the installation of several CAD/CAM systems including a distributive numerical control system and a computer graphics system. These systems will increase the efficiency of N/C part programming, N/C machining, tool design, and process planning. In addition to the acquisition of these systems, approximately 84 new N/C machines and an automated storage and retrieval system (AS/RS) will be purchased. A related MMT effort 6 82 8416 entitled, "Flexible Manufacturing System (FMS)-RIA," which parallels the REARM program is being studied, and if proven feasible, the FMS will be implemented with REARM equipment funds.

The first REARM MOD (equipment) funds were received 10 Aug 82 on MOD Project 6 82 8129 to start funding the equipment acquisition.

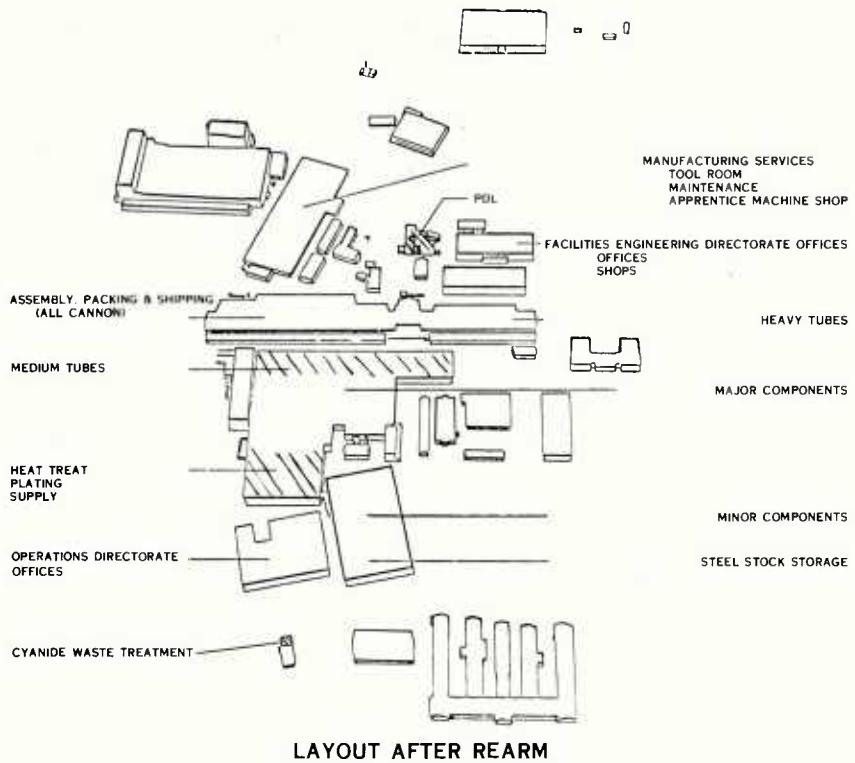
The modernization effort, when completed, will allow RIA to meet the required peacetime mission workload and, in the event of mobilization, to produce in the interim before private industry converts its production sites to meet military requirements.

REARM - WATERVLIET ARSENAL

Watervliet Arsenal has the distinct position of being the only Army manufacturing facility that produces thick walled cannon for Army. This particular capability has no comparable counterpart in American Industry. Therefore, it is very important that Watervliet maintain a strong manufacturing posture in case of mobilization. The pictures below show the existing problem that REARM is addressing.



To that end, Watervliet has embarked on a multi-year modernization effort called Renovation of Armament Manufacturing (REARM). The REARM project currently being conducted at this facility was conceived as the result of an FY74 MMT project, 6 74 7525 entitled "Process Analysis for the Modernization and Renovation of Manufacturing Facilities at WVA," which culminated with a master plan to modernize the production base of the thick walled cannon. The picture shown on the succeeding page is the manufacturing site with the shaded portion representing the completed and proposed buildings under this REARM program.



An integral part of the REARM initiative is computer technology which is making increased inroads in the manufacturing environment. This CAD/CAM technology offers great potential in maintaining the responsiveness of the industrial base for cannon in an era of shrinking resources. Watervliet is embarking on an aggressive plan to implement CAD/CAM technologies through the medium of MM&T and Project REARM. By the end of this decade, Watervliet will have in place a most advanced computer integrated manufacturing capability.

This article will highlight the flexible manufacturing system (FMS), Project No. MMT 8104, and the Distributed Numerical Control system (DNC), Project No. MMT 8154, that will be implemented using REARM funding.

FLEXIBLE MANUFACTURING SYSTEM

An initial need was to develop an automated manufacturing system capable of machining a broad range of breech mechanisms using a minimum of space and maximum efficiency in terms of machine tool utilization and reduced handling.

To date, Watervliet Arsenal has manufactured breech mechanism components utilizing stand-alone tools operating in a job shop environment. Lately, the new philosophy to maximize the combination of operations at single locations can be seen with the advent of N/C machining centers being implemented into manufacturing facilities. The Arsenal, recognizing the need to remain competitive is seeking to extend this new philosophy further into the area of FMS. The FMS concept of modular implementation minimizes risk and assures that the equipment is essentially universal by being able to be converted to a family of workpieces.

Watervliet's approach was to first establish an inter-directorate task group. Their objective was to acquire a broad, comprehensive knowledge about FMS's that closely parallels Watervliet's requirements. The data gathered by the task group is also planned to serve as an evaluation aid. The task group's final result was:

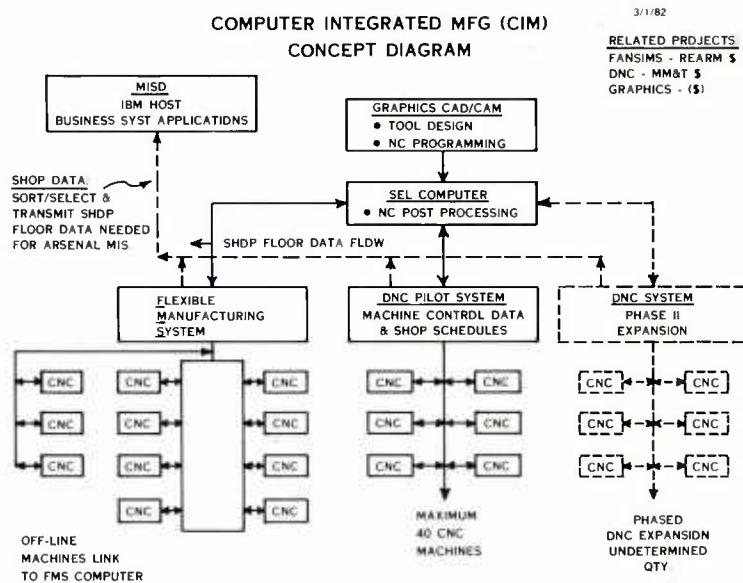
- o Contractor evaluation matrix
- o Initial design, both in-house and contractor
- o Establishment of the proper product mix
- o A procurement approach.

At present, Watervliet Arsenal is in the final negotiation stage to procure a flexible manufacturing system.

DISTRIBUTIVE NUMERICAL CONTROL

Presently, Watervliet owns approximately 80 NC and CNC machine tools. By 1987, Watervliet Arsenal will acquire approximately 120 additional CNC machine tools. Computer Numerical Control (CNC) machines are similar to NC in their general operations; however, CNC machines provide additional programming and diagnostic capabilities. Additionally, Watervliet has a Tape Preparation Center (TPC) that may be integrated with a Distributed Numerical Control (DNC) System.

A feasibility study for the installation of a pilot Distributed Numerical Control system to be located at Watervliet Arsenal was performed. This study and pilot development system is being conducted under MMT Project 6 81 8154 entitled "Computer Integrated Manufacturing for Cannon (CIM)."



Distributed Numerical Control is a computer-based system designed to coordinate and control the operation of numerically-controlled machine tools. The structure consists of three major parts in a hierarchical arrangement as indicated in the figure above. At the top of the hierarchy is the main DNC computer system. It controls the distribution of numerical part programs to run a machine tool and gathers information from each of the machine sites. Intermediate to each level of the hierarchy are communication links which permit transfer of data from level to level.

Local control devices exist at the second level. These devices are responsible for the actual control of the machine tool at each site in the plant (which are the lowest level of the hierarchy). Controls may vary widely in complexity, capability, and purpose.

The major recommendation of the feasibility study was to implement a pilot DNC system that could increase the efficiency of the N/C operations and can accomplish the following:

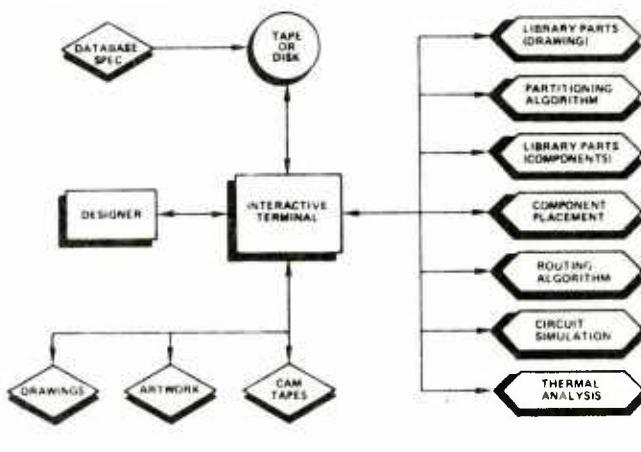
- o Provide a prototype test bed for future systems;
- o Eliminate cost of generating, handling, maintenance, and storage of N/C tapes;
- o Minimize part programming errors, prove-out time, and reduce scrap;
- o Improve N/C part programmer and NC/CNC operators efficiency.

HYBRID INTEGRATED COMPUTER AIDED DESIGN AND MANUFACTURING

The design and manufacture of a hybrid microelectronic circuit requires the interfacing of diverse technologies on the leading edge of materials sciences, equipment advancements, and the advent of computer controlled manufacturing processes. Hybrids offer distinct advantages in weight, volume, performance, power, and reliability considerations. They are an efficient interconnect and packaging technology which is cost effective only when their inherent advantages outweigh their relative design and manufacturing costs.

The objective of the first phase of this MMT Project, 3 XX 1071, entitled "Hybrid Integrated Computer Aided Design and Manufacture (HICADAM) was to formally define the future direction of material and processes in hybrid microelectronics design and manufacturing and recommend future improvements that could be implemented using automation techniques. This definition was accomplished by using a survey and past experience techniques. Both thick and thin film processes were defined and are illustrated with charts and text in the final report.

The design process includes criteria for technology selection, the logical, electrical, and physical definition of detailed design and a description of general process of electrical schematic generation. The project also produced a description of proposed future manufacturing technology projects based on the projected needs and currently planned projects. In addition, there is an architecture of design manufacturing and test of hybrids.



CAD/CAM System Attributes

The benefits derived thus far from this project are a thorough definition of the design and manufacturing processes that are used in the production of hybrid microelectronic modules.

ELECTRONIC COMPUTER AIDED MANUFACTURING

Electronic equipment manufacture has increased its portion of the total DoD budget in recent years. At present, there are available systems for some of the processes that are necessary for the computer-aided manufacture (CAM) of electronic components and subassemblies. However, these CAM systems concentrate only on one or more, but not on all of the processes that concern the manufacture of a component or subassembly of electronic equipment. The major problem then, is one of integration or compatibility between the various CAM systems for electronic equipment.

The MMT effort, 3 83 1075, entitled "Electronic Computer Aided Manufacturing" (ECAM) is a program to develop a Tri-Service method for improving design, manufacturing and testing of military electronics equipment through the use of computer aided and automation technologies.

This project will establish the present electronic factory baseline, the future factory for military electronics. A Tri-Service program to demonstrate and implement the future electronics factory will be defined.

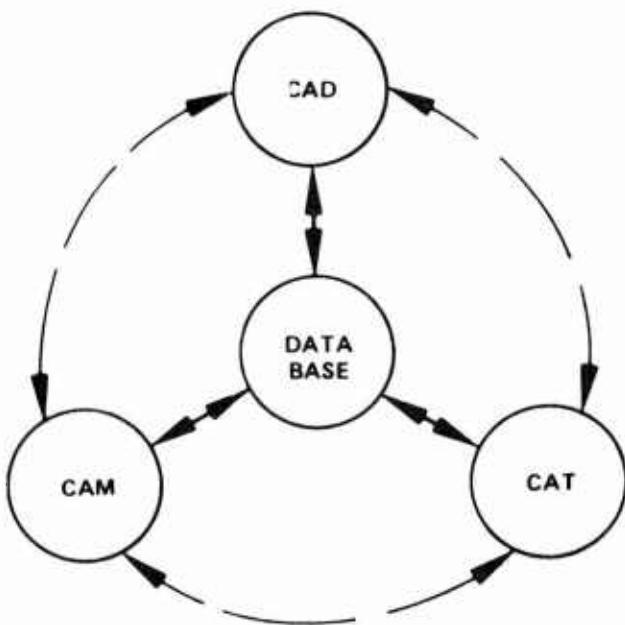
The electronic focus of ECAM will be on the following electronics devices and subassemblies:

- o Integrated Circuits
- o Hybrid microelectronics
- o Printed Circuit Boards
- o Panels, Covers and Chassis
- o Cables and Harness
- o Wire Wound Magnetic Components
- o Electronics Assembly

The definition of the present electronics factory will be accomplished using methodologies developed by the Integrated Computer Aided Manufacturing (ICAM) program and other analysis. The definition will result in an architecture of design and manufacturing for typical military oriented electronics in large and medium aerospace and electronics firms and small electronic specialty houses.

The future factory requirements for military electronics factory will then be established using projected needs, the future "To Be" IDEF model, technology forecasting for the electronics, automation and CAD/CAM technologies and the results of other analyses. The issues to be addressed

ECAM Concept



Integrated Computer Aided Design, Manufacturing and Testing System

in establishing future factory include human factors, redundancy considerations, group technology, computer higher level languages, data base structure, software transportability, standardization, modular segmentation, communication, and simulation.

The Electronic Computer Aided Manufacturing (ECAM) program is a Tri-Service funded and coordinated effort to reduce costs, shorten cycle time, and improve the readiness of military electronics manufacture. The program is presently in the definition phase under contract to Battelle Columbus Laboratories. The results of the effort will be a Tri-Service plan of demonstration and implementation for a phase II that will be executed in the 1983 - 1988 time period.

200 FABRICATION

PRINTED WIRE BOARD AUTOMATIC WAVE SOLDERING PROCESS CONTROL

FLEXIBLE MACHINING SYSTEM (FMS)

PROJECTILE FABRICATION

0 LOUISIANA AAP

- 0 MONITORING/CONTROL ROOM
- 0 ROTARY HEARTH ROOM
- 0 HEAT TREAT, QUENCH, TEMPER & COOL SYSTEM

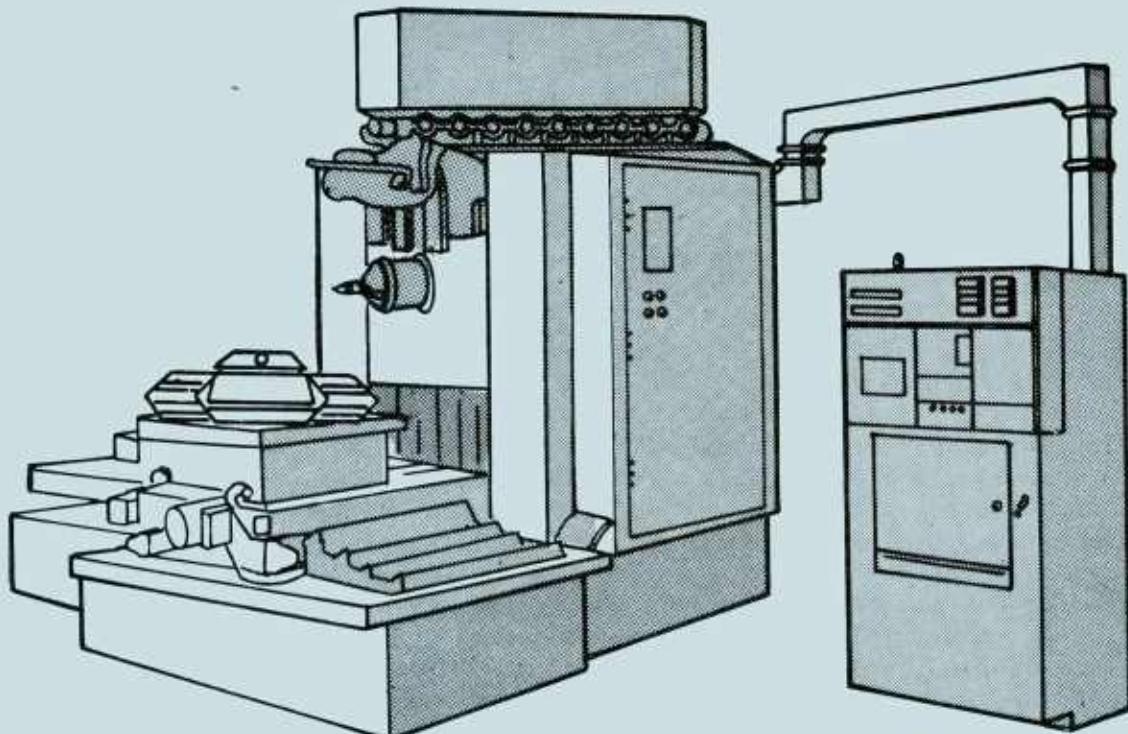
0 MISSISSIPPI AAP

- 0 FORGING
- 0 TOOL ROOM CAD SYSTEM

0 LONE STAR AAP

- 0 MODERNIZED 105MM MELT POUR FACILITY CONTROL SYSTEM
- 0 MODERNIZED DETONATOR FACILITY CONTROL SYSTEM

200 FABRICATION

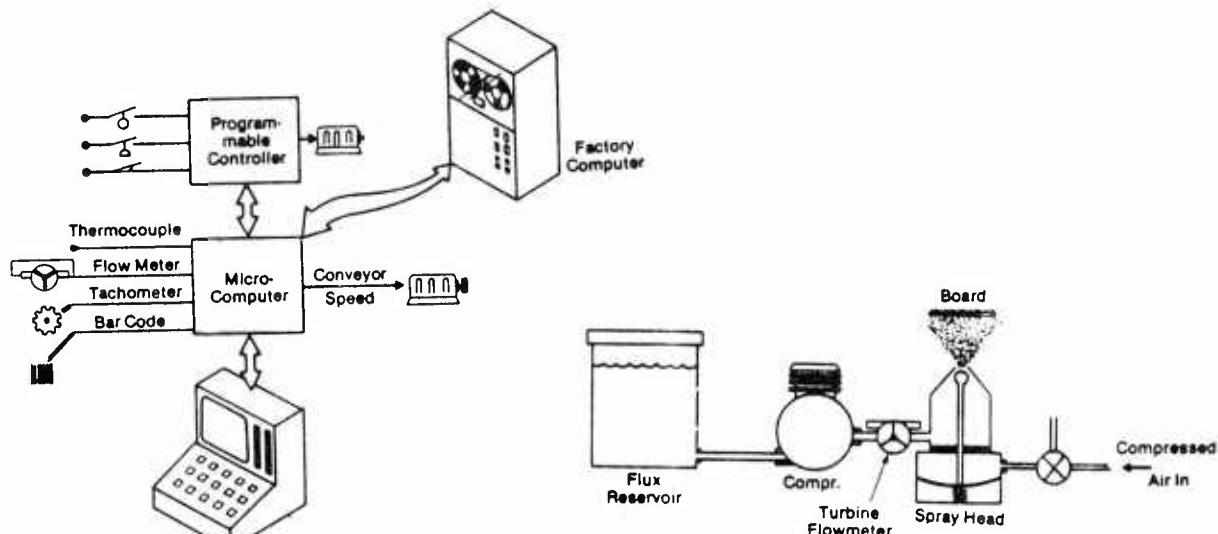


This technology area serves as a focal point for all other technology area activities. Efforts categorized into this area are directed toward increasing the productivity of manufacturing by systematically applying computer technology to all functions which directly and indirectly participate in fabricating parts. The use of Numerical Control (NC) Machine Tools is illustrated as an example of fabrication.

PRINTED WIRE BOARD AUTOMATIC WAVE SOLDERING PROCESS CONTROL

Wave soldering is used in the electronics industry for soldering printed wiring assemblies. Tens of thousands of joints can be soldered per hour by this process. If a process variable goes out of control, many defective joints can result in a short time. Satisfactory soldering in the wave soldering process depends upon a combination of interacting conditions and materials including solderability, flux activity, flux application, preheat source temperature, conveyor speed, solder temperature, solder wave shape, area of contact, solder wave surface conditions, and the heating rate of the assembly itself. The process of selecting a set of conditions to solder a particular assembly is based mainly on experience of the operator supplemented by trial and error. On most wave solder machines, only temperature is controlled while the other variables are fixed and presumed to remain constant. Since no measurements are made, except for temperature, changes in conditions may go undetected allowing the production of many defective joints.

The objective of this MMT project (R 78 3171) was to apply advanced system optimization techniques to high volume wave solder process control equipment. The schematics below depict the Control and Fluxer operation. Reduction or elimination of a large number of hand operations formerly under the control of the wave solder machine operator was desired. The control equipment would provide automatic control of critical wave soldering process variables by the use of sensors, programmable solid state controllers, and a relatively inexpensive microprocessor.



Control Schematic

Fluxer Schematic

The addition of a microcomputer to the system provides for (a) communication with the factory computer system for centralized maintenance of an inventory data base and for setting the proper conveyor speed; (b) automatic computer entry of board identity by means of a bar code label;

(c) measurement of flux flow, conveyor speed, and temperature to verify proper system operation; and, (d) presentation of system error messages on a video display screen.

The automatic wave soldering system was installed at Westinghouse Electric Company, Baltimore, Maryland. Systems supported at Westinghouse include DIVADS, RPV, F16 and ALQ131. To date, a production evaluation of the wave solder machine has demonstrated that the modification to it and to the process are cost effective. It is estimated that annual cost savings for inspecting and touch-up of wave soldered printed wiring assemblies will exceed \$1 million at Westinghouse Electric Company.

FLEXIBLE MACHINING SYSTEM

PILOT LINE FOR TCV

COMPONENTS (PHASE I)

The economics of scale achievable in mass production industries are usually substantial. In machining, for example, the unit cost of mass-produced items is commonly one percent of the unit cost of the same item produced at low volumes. Mass machining operations make extensive use of highly automated integrated systems which are dedicated to individual parts. Because the machines are dedicated, large quantities of parts are needed to amortize the large capital investments required.

Parts for tracked combat vehicles are typically not manufactured in large quantities due to limited requirements; thus, mass production technologies are not being utilized.

The advantages of mass production can be realized in producing medium quantity size lots by applying a concept known as Flexible Machining System (FMS). The objectives of the Army's FMS Program are to enhance FMS technology and solve selected technological problems that are currently limiting the application of the concept. One goal of the program is to see six to eight machining systems operating in the Army contractor community.

The entire FMS Program is a multi-year, multi-phase undertaking. The program has four tasks including: Task I - System Configuration and Evaluation, Task II - Simulation Development, Task III - Hardware Evaluation and System Architecture, and Task IV - Software Architecture. Each phase of the program will deal with each of these tasks.

The project was initiated at TACOM under MMT project T 79 5082, and generated a generic base by which FMS systems can be designed, evaluated, implemented and operated. The result of this work is a multiple volume handbook which is presently being prepared for release and public distribution. Current work involves project contractor support to the following DOD contractors that are involved in implementing FMS Technology: FMC, Hughes Aircraft, G. E. Pittsfield, and Rock Island Arsenal.

COMPUTERIZED SYSTEMS

AT

LOUISIANNA ARMY AMMUNITION PLANT

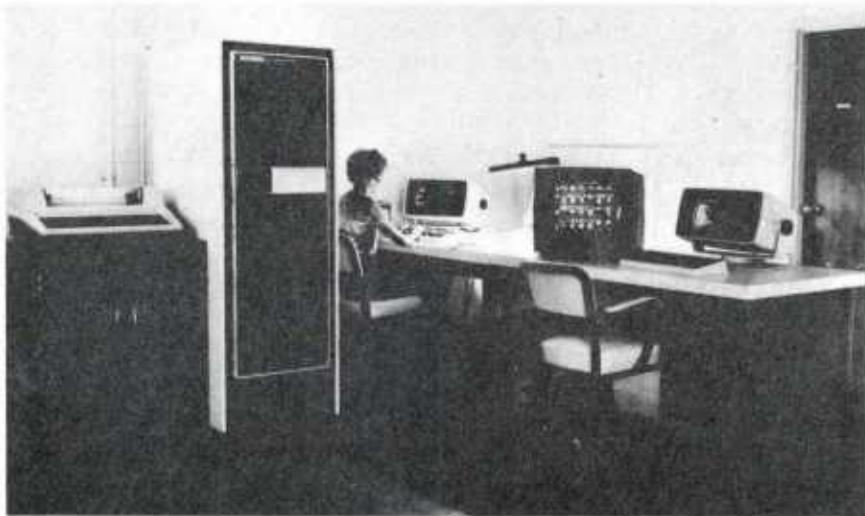
To produce the M483A1, 155mm projectile the Army has enlisted the services of two ammunition plants; one existing and the other under construction. This article will address these plants.

Under various facility modernization projects Louisiana Army Ammunition Plant has improved its industrial position by constructing and implementing several computerized facilities within its plant, three of which will be summarized. They are:

- ° Monitoring/Control room
- ° Heat Treat, Quench, Temper & Cool System
- ° Rotary Hearth Furnace

MONITORING/CONTROL ROOM

The system monitors the production of the 155MM projectiles from a point following the hot concentricity process to and including the marking process immediately prior to assembly. Utilizing a computer, the system indicates each machine, gage (automatic) and inspection station by its name, group number, and quantity of machines in the group on a color graphic display. See Figure below. Additionally, all the storage and buffer parts are indicated within the system.



MONITORING/CONTROL ROOM

The system does not perform direct control functions on any part of the production line. It presents information about the line in various forms.

ROTARY HEARTH FURNACE

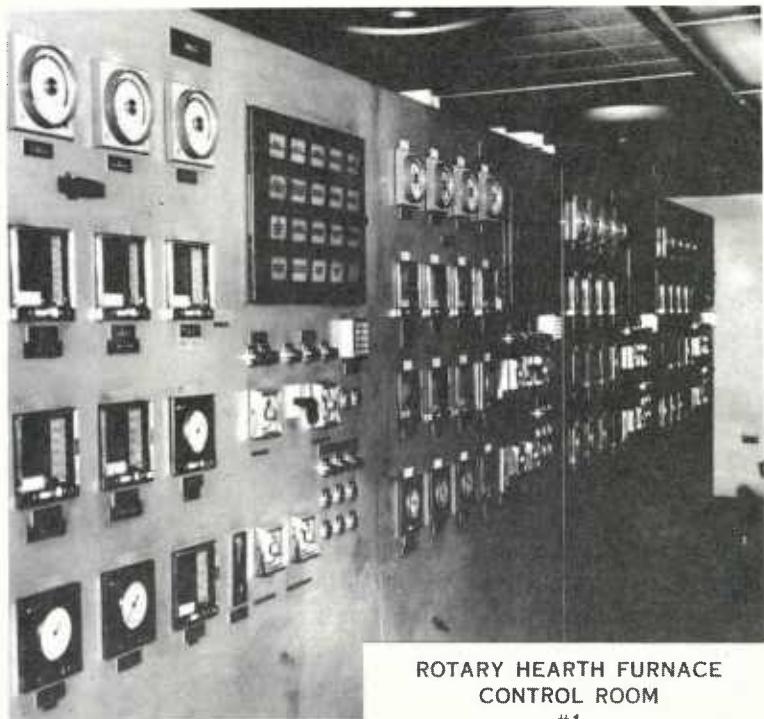
Louisiana Army Ammunition Plant has four billet heating furnaces in the metal parts manufacturing line. These furnaces were installed under a Modernization Project (AMC 5702272) in the time period 1970 - 1974.

The Furnace System is a direct gas fired, controlled atmosphere, two door rotary hearth with two work manipulators, a billet conveyor system, preheater and a TV system. The furnace is designed to heat 5 inch round corner steel billets (up to 170 pounds) to $2,250^{\circ} + 50^{\circ}\text{F}$, with an atmosphere for minimum scale and decarburization obtained by controlling the fuel-air ratio.

The furnaces were proved out in acceptance tests and subsequent production runs which involved processing several hundred thousands of projectile metal parts. These furnaces exhibited superior performance.

The furnace has adequate heating and soaking capacity to heat continuously and uniformly at the rate of 180 projectile forgings or 23,000 pounds per hour.

The furnace is equipped with a memory indicating system consisting of a two-track, solid state shift register. This memory panel, of mimic display format, has 79 memory stations and allows workpieces to be loaded at the loading station, and unloaded when they arrive at the unloading station. The system will acknowledge receipt of each piece at the loading station, and once acknowledged, the memory for this position is locked into the system. Signal lamps on the memory panel indicate exact location of each workpiece as it progresses through the furnace. An emergency power device is included as a safety feature to lock in the logic for two hours should a power loss occur.



ROTARY HEARTH FURNACE
CONTROL ROOM
#1

The hardware consists of three remote terminal panels located on the production line, whose function is to relay the input point information from the machines to the computer in digital form. The computer has 256 KBYTES of memory, a real time clock, 10MYBTES disk drive (5MB fixed and 5MB removable), dual diskette drive (315KB per diskette) and controllers for communication with RTP's, CRT's (two black and white consoles and one color graphic display), a printer (for hard copy data) and a battery back-up providing 72 hours of operation in case of power failure.

The software for the monitoring system is called LAAP and operates from the foreground black and white console using the fixed disk as mass storage of information for later recall. The second black and white console (background) is reserved for support programs as well as other programs developed by the user in BASIC, FORTRAN, OR ASSEMBLER.

The operator has available on the color graphic CRT eight graphs (one overall and seven sections) which enable observation of real time part flow and count on the productifon line by machine or group of machines and storage/buffer status. Alarms will flash on the foreground CRT terminal indicating machine failures and starve/choke conditions to and from machines, providing timely correction and eliminating excessive downtime.

At the end of each shift, the data collected is printed out in the form of a production report which includes by machine: operation time, design rate, parts produced, rejects, downtime and calculation of percent rejects, productivity activity, MTBF, MTTR, and group totals.

The display on the color graphic CRT enables timely action by manufacturing personnel - such action involves directing resources (labor, material, etc.) where they are needed before the situation becomes critical.

HEAT TREAT, QUENCH, TEMPER AND COOL SYSTEM

The Heat Treat Furnace Systems (4 each) are dedicated to the manufacturing of 155mm Projectile Metal Parts on Area Y at Louisiana Army Ammunition Plant. The system consists of a multistage automatic system designed to provide the desired physical properties on a continuous batch arrangement. The bodies are conducted through the system on trays that hold 36 bodies per tray. The equipment, when filled, automatically admits and discharges a tray at 12 minute intervals.

The equipment consists of a heat treat furnace, atmosphere gas generator, quench system, tempering furnace, and cooling arrangement -- all automatically monitored and controlled to provide a clean non-decarburized projectile body.

The hardening furnace is a radiant tube fired, atmosphere controlled, roller hearth furnace. The tempering furnace is a direct fired, recirculating air furnace with roller hearth arrangement.

This entire heat treatment complex is centrally controlled. The Series 2700 Digital Process Control System utilizes an indicating and recording system for all process variables and operates on an adjustable time basis, giving time, furnace zone, temperature, carbon concentration, and furnace speed. The controls monitor the gas generators, the hydrocarbon enriching gas for furnace Zones 3 and 6, and the air ratio control for the reaction tube of the endothermic gas generators.

The heat treat systems were procured and installed under modernization projects. Since their installation they have successfully heat treated several hundred thousands of projectile metal parts.



HEAT TREAT CONTROL ROOM

COMPUTERIZED PROCESSING

AT

MISSISSIPPI ARMY AMMUNITION PLANT

Under PIF 3142 project, an 7,200 acre ammunition plant is under construction at the NASA, National Space Technology Laboratories located in Picayune, Mississippi. This entire plant's primary function is to produce the M483A1, 155MM Projectile with a designed plant capacity to exceed 20K rounds per month. Since this facility is currently under construction, attention will focus on the Metal Parts Building which is nearing completion.

The Metal Parts Building features several CAM applications, however, this article will highlight the forging operation and the CAD system used in the tooling operation for the projectile.

FORGING

The initial operation used in the production of the M483A1 Projectile is the forging process. This operation consist of an series of subfunctions (e.g. Heat Bar, Hot Shear, Cabbage, Backward Extrude, Pierce Nose) which are controlled by a single operator utilizing an Westinghouse Model 2500 computer connected with a Hewlett Packard HP2649 terminal with graphical display. See picture below. A schematic and brief description of this process follows.

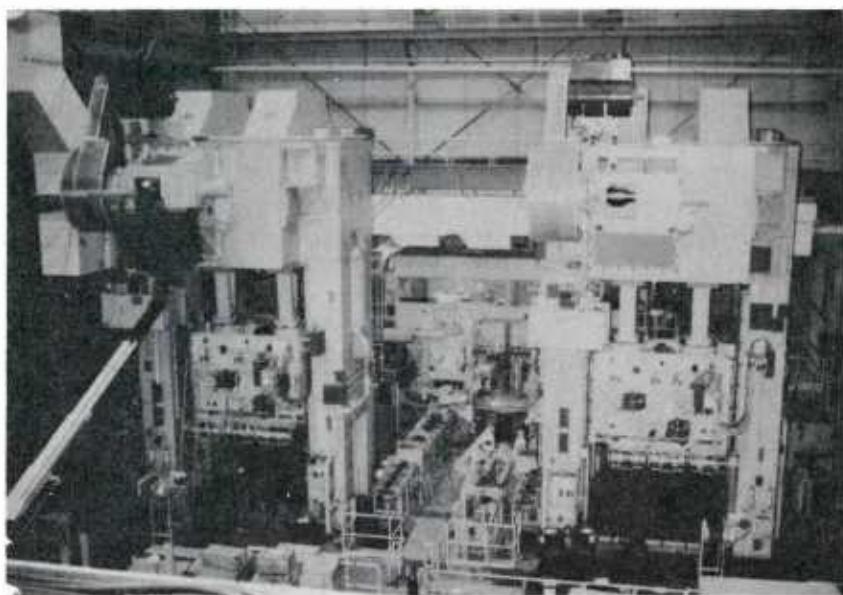


Figure 1 - M483A1 Projectile Forging Presses
with Control Center in Background

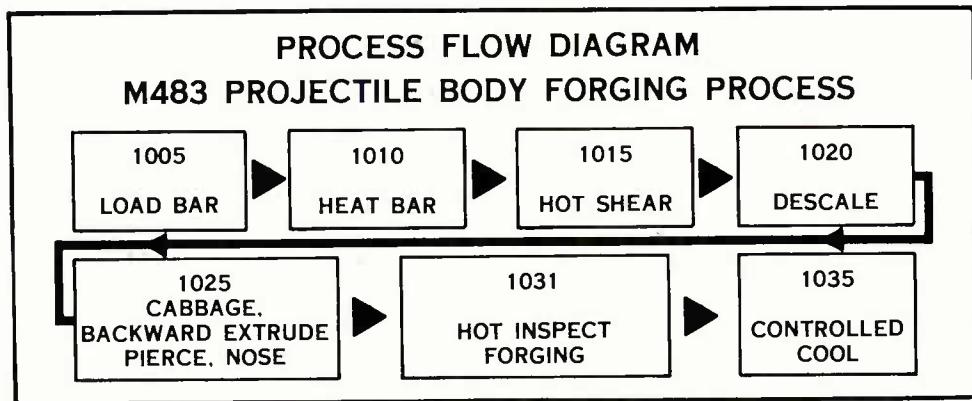


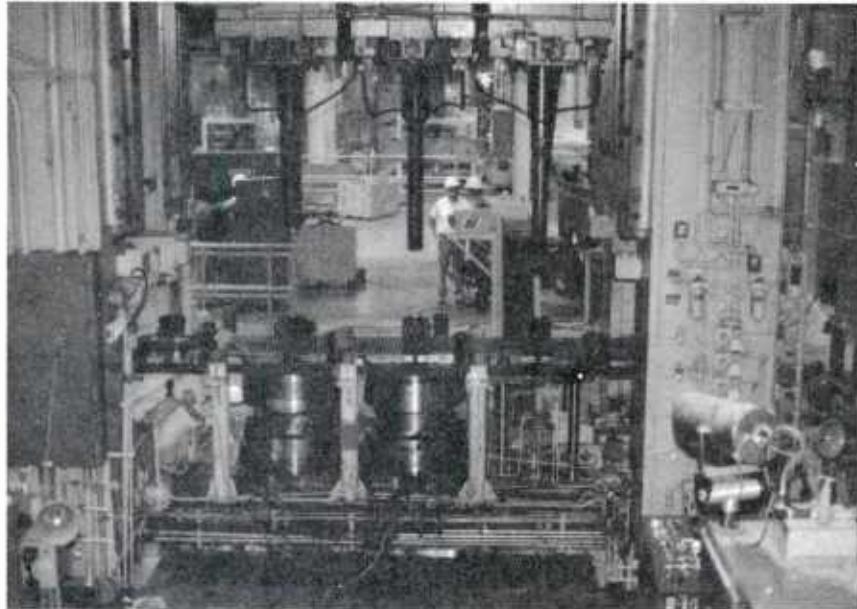
Figure 2 Forging Process Diagram

Heat Bar. Upon receiving electrical signal from the induction heater, the bars at the in-feed station will be driven toward the heater. The bar will pass through an "out of camber tolerance" gage as it moves toward the heater. If the bar is out of tolerance, its travel will be aborted before it enters the heater, and will be placed on the reject table. Another bar will be automatically fed into the in-feed station and driven toward the heater when a previous bar has been rejected. An entry set of hydraulic pinch rollers grasps the bar prior to its entrance into the heater. This first set and subsequent sets of driven rollers propels the bar through the heater. As the bar passes through the heater coils, it is heated from ambient to forging temperature (approximately 2200°F).

Hot Shear. As the bar enters the hot shear, it is automatically stopped at the proper length by the present back gage. This operation is performed by utilizing the computer output from Operation 1005. A hydraulic clamp holds the bar on the shear entry side during the shearing stroke. A depressing table on the exit side pre-loads the mult to insure a smooth cut. After shearing, the mult is automatically weighted. Mults of proper weight proceed to the next operation. Mults of improper (over or under) weight are transferred to a holding area for manual inspection and possible rework. Mult temperature is measured at this point and mults that are too hot are transferred to a scrap bin for disposal.

Descale. Mults are conveyed through a high pressure water spray which descales the hot mult. As the mult emerges from the descaler unit, it is conveyed to a mechanism which elevates it to the press feed level. At this point, the mult passes another heat detector to verify proper temperature for forging. Mults of improper temperature are diverted to a tote bin reheater holding area for processing through the mult reheater at a later time. If the mult is of proper forging temperature, it is automatically deposited in the loading station of the forging press transfer mechanism.

Cabbage, Backward Extrude, Pierce Nose. The mult is automatically transferred through successive cycles of the 2500-ton forging press where the cabbage, backward extrusion and nose piercing operations take place. The forging then exits on to a conveyor for transfer to the next operation



Hot Inspect Forging. The forging passes through the hot forge gage where length and concentricity are measured. If the forging is out of tolerance on any of the attributes, it is metal stamped "R" before passing to the slow cool furnace. "R"-stamped forgings are manually removed from the line on the exit side of the slow cool furnace, and inspected to determine rework possibilities. Rejected forgings are not removed from the conveyor prior to slow cooling due to the high temperature build-up this would create in the holding area, and the rapid cooling rate if the forging does not pass through controlled cool.

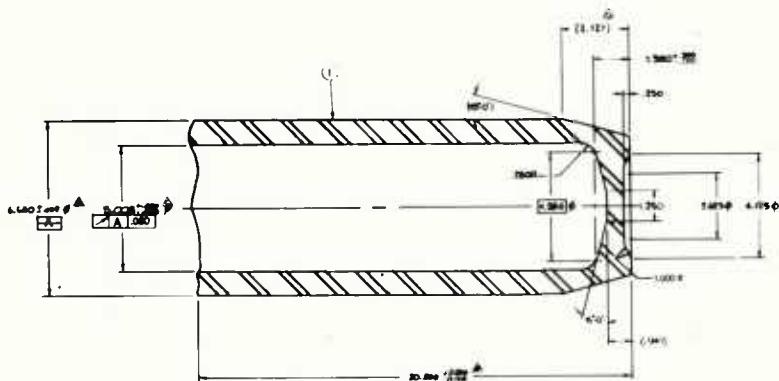
TOOL ROOM COMPUTER AIDED DESIGN SYSTEM

The tool room is dedicated to producing and reworking the tooling required by the forge room located in the Metal Part Building and the press operation located in the Cargo Metal Parts Building. This support is accomplished partially by the utilization of computerized equipment to produce NC tapes for machinery located on the tool room floor. The current system consists of the following listed equipment:

- a. Digital PDP - 11/34 CPU with 2RL01 hard disk drives.
- b. MDSI 150 Terminal with tape reader/punch and dual floppy disk drives
- c. LA38 DEC writer IV terminal
- d. Hewitt Packard Plotter
- e. DEC VT 100 Alphanumeric CRT Terminal

The system function can be briefly described in two steps:

a. Step 1 - Drawing Conversion: Using a shop oriented computer language called Compact II a free formatted program which describes the geometry involved in part definition is written. This hand generated program is transmitted to the computer via keyboard from three optional terminal (Digital LA36, LA38, UT100). The figure below is an example of the typical drawing that is converted.



b. Step 2 - NC Tape Preparation: The initial data is then converted by the post processor to machine language. Currently verification is done by utilizing the HPA-A four pen plotter as an aid. After verification the NC tape is manually loaded into the CNC control unit. After a part is run using the initial tape an optimized tape is generated featuring all edited changes for future production.

In addition, to the supporting role, other benefits can be realized, e.g. length of tape, time to machine which includes tool changes, rapid traverse and cut time to aid the scheduling calculation process.

MODERNIZED 105MM MELT POUR FACILITY

CONTROL SYSTEM

Lone Star's modernized 105mm melt pour facility is being constructed under an Army facilities project 5 74 2626. Completion of the debug phase of this project is scheduled for August 1983. This facility consists of five main areas with the following major operations:

- o Empty projectile handling
- o Flake explosive handling
- o Molten explosive handling
- o Poured projectile handling
- o Riser scrap handling

All projectile handling is accomplished by cartrac conveyor and flake explosive handling is by live roller, flat belt, and contoured belt conveyor. Riser scrap is moved by bucket conveyor. Melting is continuous and explosive is pumped to pour units.

All of these operations will be accomplished automatically and in many cases, remotely.



The control system includes Taylor 1010/73 dual 16-bit mini-computer and thirteen Allen-Bradley programmable logic controllers (PLC's). The computer will monitor and control all melt-pour operations. It will directly control the temperature, pressure, and flow rate of the explosives, steam and hot water in the melt-pour building and the temperatures in the cooling building. Through the PLC's, the computer will control the process machines, the conveyor, and the material handling systems throughout the entire line. It will track each projectile through the system and maintain a work status/acceptance profile on each projectile. It will log various parameters of the system for production reports, alarm situations, and operator actions.

MODERNIZED DETONATOR FACILITY

CONTROL SYSTEM

The modernized detonator facility at Lone Star, provided by Army facilities project 5 75 2634, is scheduled for completion in January, 1983. It will process lead azide and prepare various primer mixes from as many as five separate ingredients. The processed explosive will be transferred to load buildings for use in detonators, primers and relays. These operations will be done remotely and automatically.



The control system for this facility includes a Mod Comp II computer and twelve Allen-Bradley programmable logic controllers (PLC's).

Twelve PLC's control thirteen process barricades. The PLC's are operated from the central control room, see picture. All mechanical movements are controlled by the PLC's. This includes explosive drying, screening, weighting, blending, and dispensing into explosive carriers on a cartrac conveyor.

The computer and three PLC's control the conveyor system. Carriers are moved from storage lanes into the process barricades to receive explosives. The carriers are sent to the load buildings where the explosive is removed manually. The carriers then return to the storage lanes until needed again.

The PLC's are used for the direct interface with the electrical equipment. All direct communication with the operator consoles is performed by the PLC. The PLC keeps track of which system locations are occupied and provides traffic control interlock logic. All equipment manipulations are performed by the PLC's. Also, the PLC detects any unsafe conditions and halts the appropriate subsystems if necessary.

The central computer provides all services which require data base manipulations. The central computer provides system initialization and phasedown.

All powder requests are serviced by the central computer. The central computer maintains carrier identification and provides carrier tracking. Also, the central computer provides the various status and historical reports for system analysis.

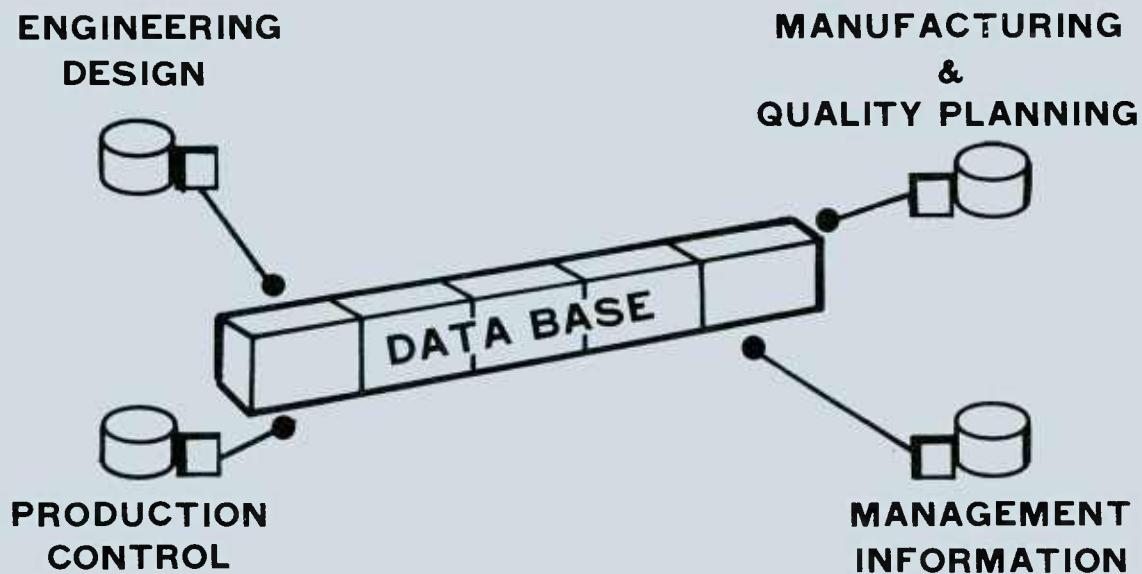
Operator requests to the material handling system are entered one of two ways. The control room operator enters requests for system initialization, status reports, and some control functions from the control room terminal. All other requests are entered by pushbuttons located at the front line bays, the cleaning bays, and in the control room.

300 DATA BASE/DATA AUTOMATION

INITIAL GRAPHICS EXCHANGE SPECIFICATION

PILOT AUTOMATED SHOP LOADING AND CONTROL SYSTEM

300 DATA BASE/DATA AUTOMATION



The purpose of Data Base and Data Automation technology is to support the integration of the many stages, subsystems and disciplines of manufacturing into the manufacturing architecture. Although CAM applications may be classified and evaluated in various technology areas, consideration should always be given to their data base/data automation with respect to coordinating and evolving into a common model of manufacturing architecture. The concept of a shared manufacturing data base is illustrated.

This is an area in which management is concerned with establishing a network of subsystems which, when integrated, will provide a total manufacturing information system supportive of planning, production, and control.

INITIAL GRAPHICS EXCHANGE SPECIFICATION

The Initial Graphics Exchange Specification (IGES) is a Multi-Governmental effort designed to serve as a receptacle for the data generated by today's commercially available interactive graphics design-drafting systems. IGES is a communication Computer-aided Design and Computer-aided Manufacturing (CAD/CAM) system. It is intended that this structure provide a common basis for the automatic interchange of data between these systems, for the transfer of data to and from external application programs, and for archiving of the data.

IGES represents an initial, organized attempt to address and resolve the interface problems that arise as a result of the introduction of the computer into the design and manufacturing environment. These problems, regardless of their origin, can be characterized by the fact that the data as produced by one system is not usable by another system. It is the common experience of many users that the resolution of the interface problems associated with creating, transmitting, storing, and retrieving of computer data is vital in order that full productivity can be realized.

Recently demonstrations were conducted at various locations, two of which have publicized their results. In the paragraphs below, a brief summarization of the results from the Bendix, Kansas City exhibit and the demonstration conducted at the National Computer Graphics Association's (NCGA) third annual conference. The picture is a representation of the part exhibited.

IGES Used to Manufacture Mechanical Part



In the early part of 1982 Bendix, Kansas City, announced that they and Sandia National Laboratories, Livermore, have successfully designed and manufactured a mechanical part using the IGES to transfer the geometrical model data. The data was exchanged between two dissimilar CAD/CAM systems.

Design information developed on a CAD/CAM system was translated to IGES through a pre-processor at Sandia. A second vendor's post processor translated the design information from IGES to a CAD/CAM system at Bendix. The Bendix CAD/CAM system was used to generate the numerical control tape from the exchange data. This tape was used to manufacture the part.

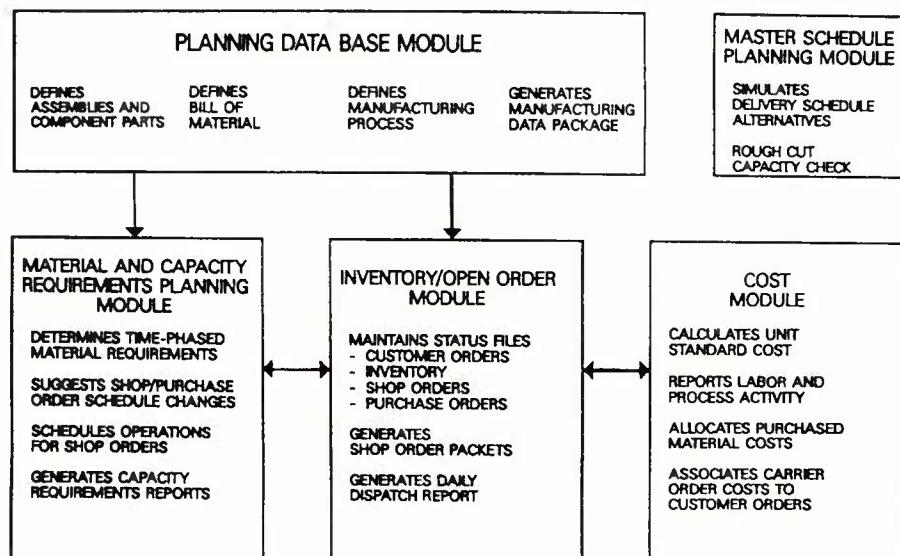
A production print from Sandia, used during final inspection, verified part accuracy. Project results indicated that both vendor-furnished translators correctly transferred the geometric three-dimensional model consisting of points, lines, and arcs.

The first public demonstration of IGES was conducted at NCGA '82. The demonstration was organized by National Bureau of Standards in cooperation with five CAD/CAM graphics vendors (Applicon, Calma, Computervision, Gerber, and Manufacturing Consulting Services). Control Data and McAuto- Unigraphics provided prerecorded tapes with sample part geometries in IGES format.

In the demo, a mechanical plate part containing drilled holes, milled pockets, and profiled edges was loaded from an IGES file into a CAD/CAM system. There, it was modified according to suggestions from the audience; then it was transmitted back to the IGES file, and from there it went to a different CAD/CAM system of further display and modification.

PILOT AUTOMATED SHOP LOADING AND CONTROL SYSTEM

Rock Island Arsenal (RIA) has completed an MMT project (7580) to upgrade its production planning and control capability thru development and implementation of a comprehensive computer based system. The Pilot Automated Shop Loading and Control System (PASLACS) consists of five modules as shown in figure below.



The Planning Data Base Module is used to define the products manufactured by RIA and the information needed to make or buy each assembly, component, and raw material item. The data base files include part descriptions, bills of material, and manufacturing process and routing data.

The Material and Capacity Requirements Planning Module is used to perform planning and scheduling functions. The module determines time-phased material requirements and suggests ordering actions for both manufactured and purchased components. Reports are generated which indicate if open purchase or shop orders need to be rescheduled due to changes in requirements. In addition, the module provides the information needed to plan and control capacity.

The Inventory/Open Order Module is used to process and maintain the status of customer orders, and purchase orders. It also produces a daily dispatch report for each department which lists the current schedule and priority of each manufacturing operation.

The Cost Module is used to summarize and report labor and process cost activity, provide estimating and cost analysis data, and associate costs for combined orders back to individual customer orders.

The Master Schedule Planning Module is used to develop end item master production schedules which can be accomplished within expected capacity constraints. It provides the capability to quickly simulate delivery schedules, and perform rough cut capacity checks.

All elements of the system are operational and in use at RIA. However, implementation of some portions of the system, which are being phased in by product groups, will continue through the end of 1983. The completed installation of PASLACS will provide management with the visibility and control required in a job shop environment to produce benefits such as:

1. Improved ability to assess the impact of new workload, revised delivery requirements, and revised priorities.
2. Improved delivery performance through early identification and resolution of problems and bottlenecks.
3. Reduced manufacturing costs from setup reductions and higher labor efficiency.

During FY 83 and FY 84, RIA will be implementing a related facilities project (6966) entitled Factory Automated Communication System (FACS). This project will replace an existing shop data collection system used for labor reporting with an expanded system capable of supporting all of the manufacturing directorate's data collection devices (shop data collection units, video displays, and printers) connected to a central computer interfaced to the PASLACS system. It will be used to report

labor, inspection, inventory, material movement, and time and attendance information, and to obtain related status information maintained in the central computer files.

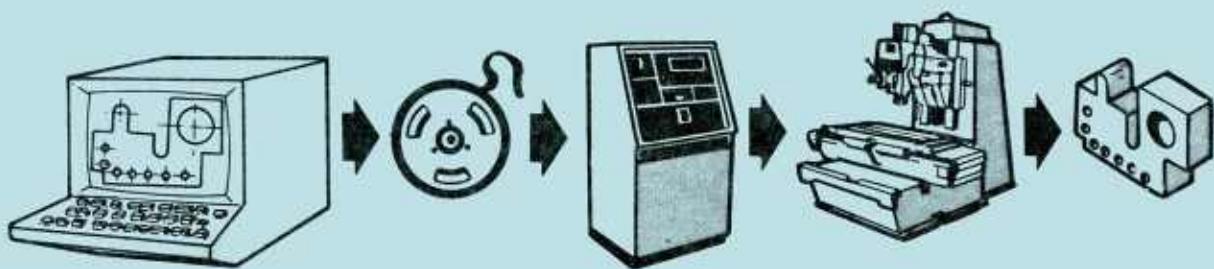
In addition, RIA has a three year (FY 82 thru FY 84) MMT effort underway to build upon the foundation established by PASLACS and FACS. This project, On-Line Production Information System (OPIS), will initially replace most batch processing functions in the PASLACS system with on-line data base oriented processes utilizing the FACS terminal equipment for communication. Following this step, advanced production engineering support systems will be developed for process planning, methods and standards, industrial facilities planning, and maintenance planning.

400 CADCAM INTERACTION

IMPROVE FOUNDRY CASTING PROCESSES

GEAR DIE DESIGN AND MANUFACTURING

400 CAD/CAM INTERACTION



The purpose of this technology area is to establish subsystems and procedures which will integrate the efforts of product design and manufacturing. The underlying concept is that of a common data base between engineering and manufacturing.

In these types of efforts, the definition of manufacturing architecture is extended to include the design function, its interaction drivers and computer assisted tools to increase the effectiveness of these interactions. Interactive graphics is one of the computer assisted tools illustrated in the picture above which supports a data base for manufacturing. The first three efforts in this section represent installed and operational mini-computer CAD/CAM systems. The remaining efforts represent the status of software development for metal processing and die making.

IMPROVE FOUNDRY CASTINGS PROCESSES

TACOM is involved in an MMT effort (5014) to improve casting processes utilizing computer aided flow and thermal analysis. This article is to update the reading audience of their progress from the previously published CAM Highlights dated April 1981.

The CAD/CAM casting process is being developed as an aid to casting engineers in designing better steel castings in a fraction of the time presently required. The computer routines incorporated drafting programs and computer assisted calculations relative to heading and gating. Evaluation routines allow 2-D and 3-D heat flow analysis with a minimum of interaction from the user. See Figure 1 for description of the major steps for forging die design. The objectives and the present stage are briefly described herein.

This update discusses Phase I of the development of a system for the planning of armor steel castings with the aid of computers. A system of programs, is being developed by University of Pittsburgh, Blaw Knox and the Battelle Columbus Laboratories under contract to TACOM.

The CAD/CAM casting process is aimed at providing a computer aided design tool for the casting engineer. It represents an integrated set of programs covering the two following areas:

a. A framework for utilizing computer graphics to handle and display cross-sectional geometry as well as calculate geometric parameters relative to heading and gating.

b. Evaluation of mold cavity design by finite element analysis of solidification process. Facilities are provided for defining a simplified process and a simplified three-dimensional mathematical model of the casting. Actual mesh generation for the analysis is completely automatic. Output in the form of heat transfer plots and solidification maps will serve to predict casting soundness.

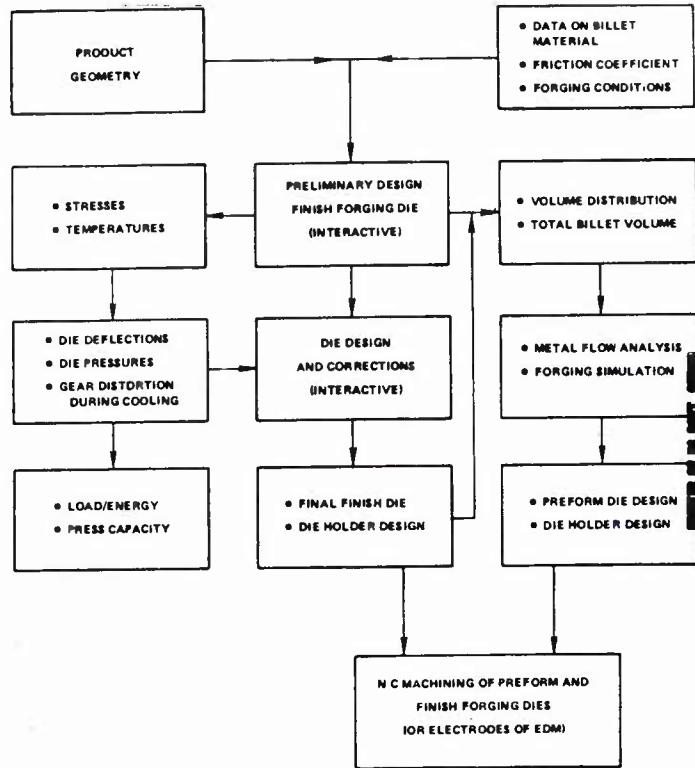


Figure 1

The overall design of the CAD/CAM casting process is illustrated in Figure 2. The design process is separated into two distinct functional routines which are mold cavity design and casting process simulation.

o Mold Cavity Design - These routines are primarily a drafting tool that make use of two input devices and a graphic screen. The input devices are a function keyboard and a digitizing tablet. With the keyboard, coordinates of points describing the perimeter of a cross-section can be input. Twenty-five points/cross-section can be used. With the use of different function keys, the points are joined by straight lines, arcs, or curves. This cross section is then viewed on the graphic screen.

o Casting Simulation - To evaluate the mold cavity design, routines are available to perform heat flow and fluid flow simulations. The geometry of the mold cavity must be again described to the computer in terms of simple geometrical shapes called "zones." The zones are then divided into nodes and elements creating data input files for the analysis routines. From the information gathered thus far, the nodal mesh for finite element analysis is generated automatically and the routines permit two-dimensional and three-dimensional heat flow analyses.

To date, this has been the recorded progress; however, in subsequent development of the CAD/CAM casting process, the experimental thermal data obtained from the test plate castings will be incorporated into the programs. Mechanical properties and radiographic soundness of the test plate castings will be correlated with the computed and experimentally determined thermal conditions during freezing of the plate castings.

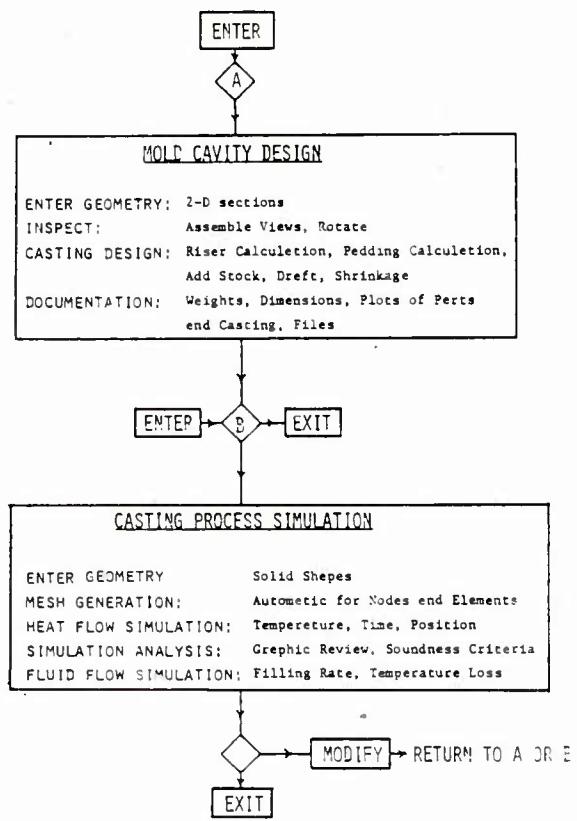


Figure 2

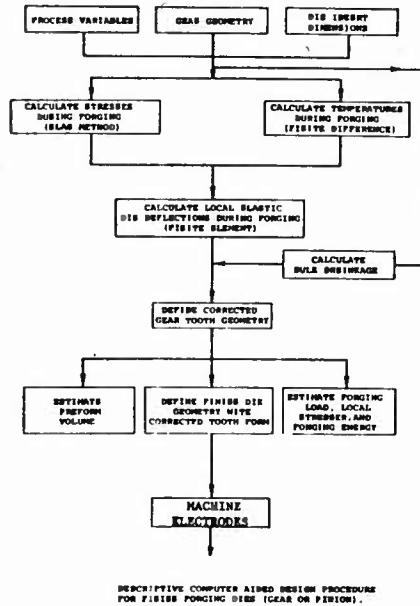
GEAR DIE AND MANUFACTURING (UPDATE)

At present, TACOM is sponsoring an MMT effort (5024) to apply computer aided manufacturing technology to gear design and manufacture.

Phase I of the effort was documented as being completed in April 1981. This is a summarization of accomplishments to date.

In phase I of this program, a general purpose CAD/CAM technique was developed for producing precision - forging dies for the family of spiral bevel gears. This CAD/CAM method uses the following input data:

- o The specifications and overall dimensions of the spiral bevel gear to be produced.
- o Data on billet material under forging conditions.
- o Friction shear factor, describing the friction shear stress at die-material interface.
- o Forging conditions, i.e., temperatures and deformation rates.



Using these input data, the CAD/CAM method developed in this project performs the following computational steps:

- o Transform the dimensional input data into coordinate data to represent the tooth surface and display the results graphically on a Cathode Ray Tube (CRT). In addition, a simulation of the motion of a machine used in the cutting process of spiral bevel gears to better define the tooth geometry is performed.
- o Starting with the initial calculated tooth geometry, the following factors were computed: forging stresses, forging load, temperatures, elastic die deflection, thermal and mechanical shrinkage, and forging volume. Thus, a corrected die geometry and required billet size was derived.
- o The final computation is to determine the settings of the spiral bevel gear cutting machine utilizing the previously calculated, corrected die geometry. The cutting machine's function is to machine the electrodes which are used for Electro-Discharge Machining (EDM) of the dies.

In addition to CAD/CAM die designs, Phase I effort also included the development of a computer program for the finite element analysis of the stresses in a spiral bevel gear - pinion drive system.

The results of Phase I are being used in Phase II to demonstrate the effectiveness of the developed CAD/CAM system by producing at least 20 spiral bevel gear - pinion sets.

500 PLANNING AND GROUP TECHNOLOGY

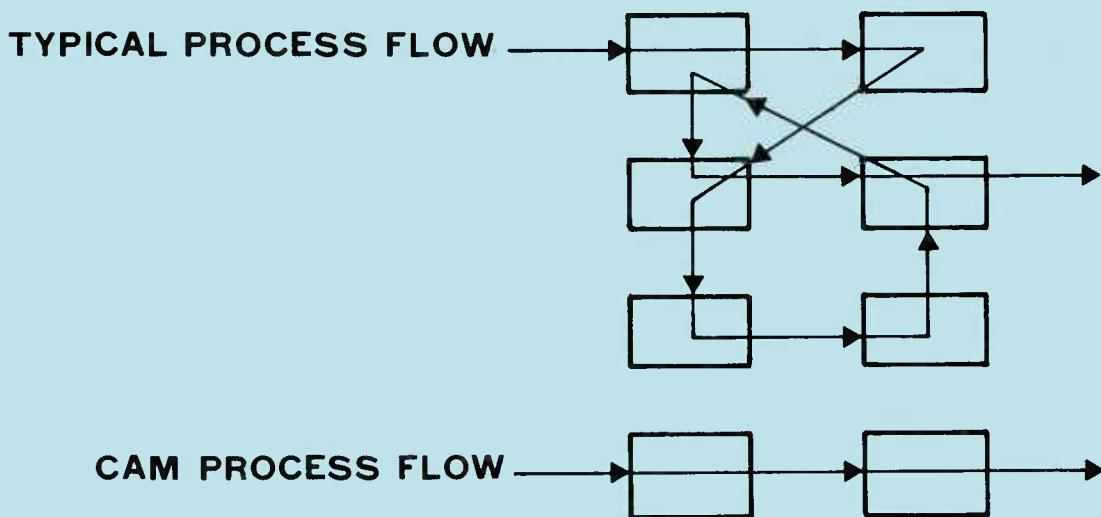
COMPUTER AIDED PROCESS FOR MACHINED CYLINDRICAL PARTS

GROUP TECHNOLOGY OF WEAPONS SYSTEMS

GROUP TECHNOLOGY REQUIREMENTS DEFINITIONS FOR ELECTRONICS

FIRE CONTROL MODERNIZATION PLAN

500 PLANNING AND GROUP TECHNOLOGY



This area encompasses efforts directed at optimizing process planning, production scheduling and control, factory layout, and other tasks that have a significant impact on manufacturing cost and which are normally performed by indirect personnel. An example of improved factory layout is illustrated.

COMPUTER AIDED PROCESS PLANNING

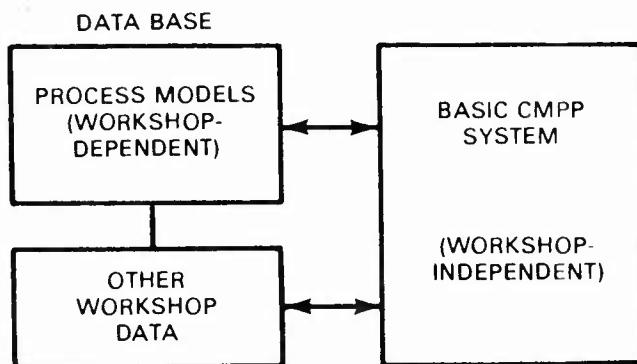
FOR

MACHINED CYLINDRICAL PARTS

Machined cylindrical metal components are a significant cost driver for missile systems and other DoD procurements. Manual methods predominate in production process planning for the components. This results in high process planning cost and forfeits production cost savings that could be obtained through process standardization and optimization.

This project (MMT 3 XX 1021) is an extension of a previous MMT effort (Ref: MMT 3 XX 3232) which developed the technology. The objectives of the follow-on are to standardize and reduce the cost of process planning and implement the earlier developments.

The approach taken during this effort was to design and implement a large manufacturing independent software system, Computer Managed Process Planning (CMPP). Figure 1 is a block diagram which shows the technique for Manufacturing Independence. CMPP was developed to serve as an executor of a manufacture dependent data base. The data base describes the manufacturing resources and processes of a workshop. Included in this data base are process decision modules. These models of workshop-dependent statements of process planning logic are written in special purpose, English-like language, and executed by CMPP during process planning. See Figure 2 which illustrates the process steps.



CMPP Technique for Manufacturer Independence

Figure 1

The CMPP data base consists of four files:

- o Vocabulary File.
- o Process Decision Model File.
- o Machine Tool File.
- o Cut Parameter File.

GT MANUFACTURING PROCESS PLANNING

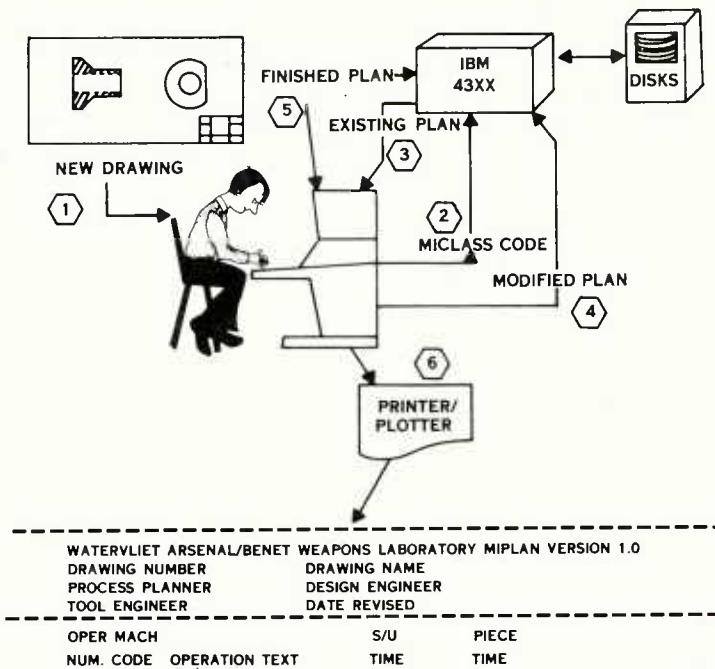


Figure 2

The performance of the process planning technical function is the heart of CMPP. The system performs three major functions:

- o Determination of sequence of operations.
- o Selection of dimensioning reference surfaces, locating surfaces, and clamping surfaces.
- o Determination of machining dimensions, tolerances and stock removal.

Considerable cost savings due to standardization and reduced man hours is anticipated. Three divisions of United Technologies are implementing the results of this program in modules as the development is completed.

GROUP TECHNOLOGY OF WEAPON SYSTEMS

In today's massive manufacturing system, one of the major problems encountered is the proliferation of designs and parts. The Army is no exception to this manufacturing ailment. Technologies have been introduced in industry and some Government installations which classify designs and parts so they may be grouped into families. These classification systems eliminate design duplication, reduce the number of parts in the manufacturing system, and develop the techniques of part-family manufacture. One such classification system was established at Watervliet Arsenal.

GROUP TECHNOLOGY REQUIREMENTS

DEFINITIONS FOR ELECTRONICS

In Government and industry there is a widely recognized need for a group technology (GT) classification and coding system for design and manufacturing of electronic components. At present, GT has been defined in terms of its usefulness in improving productivity in batch manufacturing of machine parts at Rock Island and Watervliet Arsenals. However, it should provide the key to the integration of computer aided design (CAD) and computer aided manufacturing (CAM) in any manufacturing environment, including electronics. Essential to the application of GT as the link between CAD and CAM systems, is a well structured and developed classification and coding system. The classification and coding system becomes a method for organizing (grouping) data so that it can be retrieved quickly by multiple users. This effort was ARRADCOM MMT project 8 80 0915.

Recognizing the potential benefits of GT applications in electronic manufacture, the Tri-Services Manufacturing Technology Program, through the US Army Armament R&D Command, Dover, NJ awarded a contract to the Organization for Industrial Research (OIR). OIR's objective was to survey the electronic manufacturers in order to define those characteristics which would be fundamental to a GT electronic classification and coding system.

The OIR survey conclusions revealed the following information should be captured in the standard section of an electronics classification and coding system (ECACS).

Family Categories: The following categories were identified as primary, discrete areas (functional grouping) within electronics manufacturing:

- o Printed Wiring Boards
- o Integrated Circuits
- o Electronic Assemblies
- o Electro-Optics
- o Wiring Assemblies

General Characteristics: An ECACS should capture the following general characteristics in the standard section of the code. These characteristics apply to all components to be coded. This information is necessary for design, manufacture and test engineering, and has been identified as of primary importance by all respondents. The characteristics are listed in order of importance:

- o Function
- o Dimensional Parameters
- o Electronic Parameters
- o Tolerances
- o Test Criteria
- o Annual Quantity

Forerunners of the manufacturing coding system established at Watervliet were installed at Frankford Arsenal in Philadelphia, PA. and at the Naval Ordnance Station in Louisville, KY. These systems were specifically designed to facilitate the manufacturing design phase.

Some of the results and benefits in the manufacturing and design area as a result of the MMT effort conducted at Watervliet Arsenal (Ref: MMT 6 79 7724) are listed below:

MANUFACTURING:

- o It was recognized that there was considerable variation in the manufacturing process plans for same or similar parts.
- o Grouping similar parts could result in considerable cost savings of approximately 30%.
- o It was estimated that the throughput time could be reduced by 15 to 20%.
- o The reduction in the set-up time automatically increased the availability of machine tools for production purposes. In other words, a savings of 20% in set-up time results in an increase in the capacity of that machine tool.

DESIGN:

- o Using a part recognition system, e.g. MICLASS, it is possible to search the design data file for similar parts before a new design is made.
- o Drawing standardization would yield benefits due to a decrease in manufacturing tooling costs.

This project was to be continued by Project 6 81 7724 in the evaluation and selection of a computer aided process planning system in building on the data base. The latest accomplishments for this MMT effort (Ref: 6 81 7724) are summarized in the following list:

- o MICLASS was modified and tested by Watervliet's Arsenal Operations Directorate.
- o MIPLAN was procured.
- o MIPLAN graphics support procurement has been initiated.

FIRE CONTROL MANUFACTURING

MODERNIZATION PLAN

Prior to 1975, the ability to provide rapid response for manufacturing metallic, optical, and electronic components for various military fire control was insufficient to handle the manufacturing requirements. Many of the machines and tools for fire control manufacturing were outmoded. During that period, the "state of the art" still depended mostly on the expertise of the manufacturing technicians, using limited techniques and equipment, to produce a variety of complex components.

This project's objective was to increase the efficiency and flexibility for small batch manufacture of fire control components and reduce manufacturing cost by at least 20%.

When MMT effort 6 7430 was completed in 1979, the philosophy and principles of group technology were applied as a means for accomplishing restructure and upgrading of small batch size manufacturing of fire control components. The MICLASS group technology system was used to classify and code the part drawings, analyze the design and manufacturing data, and form part families and machine tool groups for a representative sample of fire control components. Approximately 1100 fire control part drawings were coded and manufacturing process information was stored in the data base for 1/3 of the coded parts. With this series of retrieval, sorting, and analysis programs the user can readily provide computer-assisted operational, manufacturing, and management data to technical personnel.

600 MANUFACTURING CONTROL

AUTOMATIC CONTROL OF PLATING

VOICE CONTROLLED PROGRAMMING OF COMPUTERS

LAYAWAY OF ELECTRONIC PROCESS CONTROL SYSTEMS

COMPUTER CONTROLLED PRESSES PROVIDE HIGH RELIABILITY

PRECISION MACHINING OF OPTICAL COMPONENTS

COMPUTERIZED MATERIAL PROPERTIES DATA

600 MANUFACTURING CONTROL



DELIVERIES

ITEM	JAN	FEB	MAR	APR
XXX	<input type="checkbox"/>		<input type="checkbox"/>	
XXY		<input type="checkbox"/>		
XYY			<input type="checkbox"/>	
XYZ				<input type="checkbox"/>

The generic technology for producing management oriented information tools for scheduling, monitoring and controlling operations within the manufacturing environment is addressed by efforts in this technology area. It is closely related to the technology areas of Fabrication, and Planning and Group Technology. An example of a scheduling tool is a gantt chart as shown. Production manufacturing control activities historically bear the major burden for exercising the coordination of production facilities to produce products on schedule at optimum cost. Manual systems of scheduling, monitoring and controlling processes are not sufficiently responsive to a constantly changing workload environment to permit optimization of high productivity and economics offered by modern manufacturing methods and equipment. The US Army has on-going or completed several MMT projects oriented towards applying computers to assist, on a timely basis, manufacturing processes, techniques and equipment for optimizing production of Army materiel.

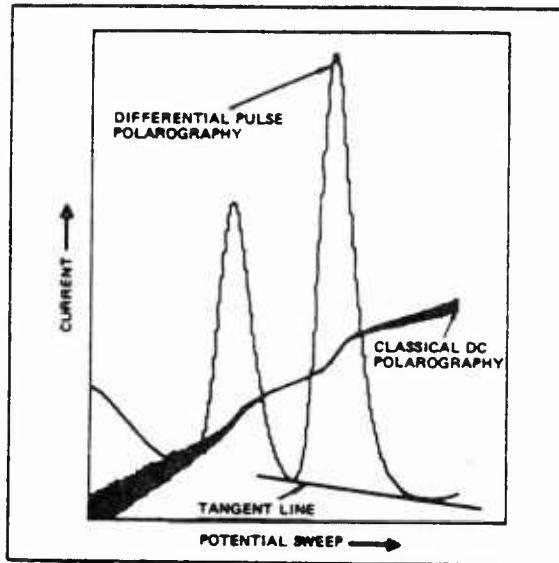
AUTOMATIC CONTROL OF PLATING

Plating lines for printed circuit boards have an extremely large number of variables which influence printed circuit board quality. These include, but are not limited to, plating voltages, current densities, time in solutions, solution PH, solution composition, cleaning and rinsing, times between baths, etc. The degree of complexity is such that manual control methods cannot maintain the tight tolerances that are required for the highest quality results.

In a typical printed wiring board (PWB) manufacturing facility, a major effort is expended in obtaining representative samples of these solutions, chemically analyzing them, computing the required additions, and making these additions in a reliable manner. This entire process is costly, prone to error, and not sufficiently time responsive for some key solutions whose composition changes very rapidly during use.

The objective of MMT Project R 78 3268 was to improve printed wiring board yield and reliability by implementing a computer controlled process of automatic solution monitoring and control system. In addition, the developed monitoring and control technology is intended to be sufficiently versatile so as to apply to virtually any solution used for PWB processing. The results of this effort produced an automatic controlled plating system by integrating sensing devices with computer control. This system is currently being used by General Dynamics Corp. of Pomona, CA. General Dynamics is involved in plating printed circuit board assemblies which are used in missile guidance systems.

The process control system includes a desk top computer, a controller/sequencer, and the polarographic analyzer. The integration of these components was designed to function in the following manner. The computer will direct all phases of the sensing and control system, handling each solution in a sequential pattern. First, sampling of each solution will be initiated so that a representative sample will flow into the sensing system along with any appropriate diluents and/or reagents. Then an analysis will be initiated and the results computed and stored in memory. These results will be compared against set point values which correspond to the optimum concentrations of the solution's constituents. Any deviation will trigger the appropriate metering pump so that replenishing can occur. The degree of adjustment will be fully regulated by computer algorithms to minimize over shoot. These steps continue until the controller/sequencer activates the pump of a specified period of time, at which time the cycle is completed.



COMPARISON OF DIFFERENTIAL PULSE AND DC POLARGRAMS

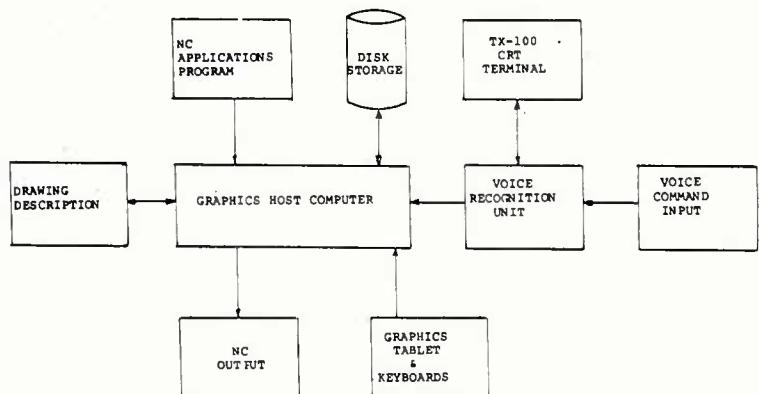
VOICE CONTROLLED PROGRAMMING OF COMPUTERS

The numerical control program preparation system currently employed at Tobyhanna Army Depot is manual, requiring a keyboard input. This type of operation is more susceptible to error than saying the word or number that the operator visualizes. Also, the programmer, while referencing the part drawing and specifications, must be knowledgeable of the keyboard functions. Thus the ability to produce NC programs becomes dependent upon the operator's ability to operate the system, second to the skill required to read and interpret drawings. The figures shown are representative of the system.



The objective of this MMT project (Ref: G 80 0001) was to improve programming efficiency by interpreting voice controlled programming technology into the NC program preparation system.

The system developed uses existing hardware and software when feasible and requires only minimum modifications to a graphic system. Vocabulary and operators' voice patterns are stored in the graphic system and recalled on command. The operator then speaks into the voice unit which interprets the command and sends it to the graphic system which will execute the command. The voice commands are used to generate APT source, geometry, tool motion, cutter location, tool information, and others. It can be easily modified for any vocabulary set.



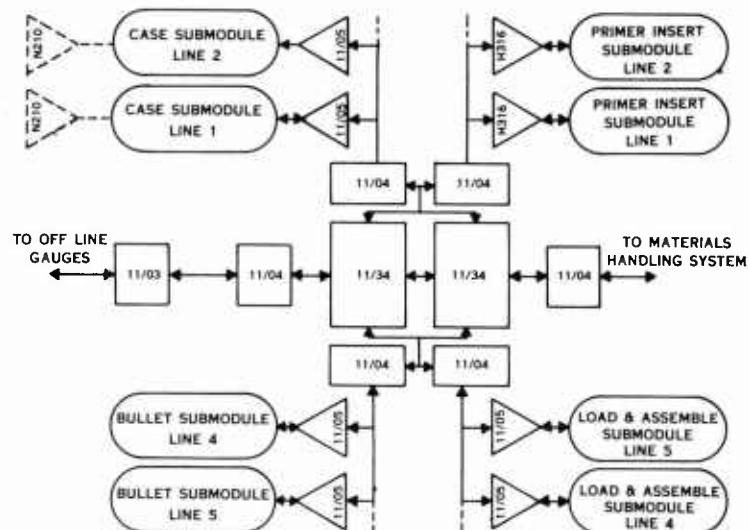
Finally, the results of this project are being integrated into an Applicon CAD/CAM System.

LAYAWAY OF ELECTRONIC PROCESS CONTROL SYSTEMS

Complex modern automated munition production lines are normally controlled by some sort of Electronic Process Control System (EPCS). EPCS's are made up of sensors, controllers, computers, interfaces, microprocessors, and software. Industrial experiences in the design and maintenance of EPCS's for layaway and stand-by are virtually non-existent. This presents a real problem to the Army; over the next 20 years, many of the EPC's will go through active and inactive periods. Nine automated lines are currently inactive and nine more are planned for layaway within four years. The objective of this program was to develop a methodology to counteract the problems associated with dormant EPCS's.

Joliet and Volunteer TNT lines were used as test sites for the project (Ref: MMT 5 78,79,80 4322 entitled "Design Criteria and Systems Characterization of Electronically Controlled Production Facilities) and were put into layaway after a baseline state of health was established. These facilities were the "first" major facilities with EPCS's "mothballed" under controlled conditions. After shut-down, the lines were cycled (start-up, check-out, and shut down) at periodic intervals. During each cycle, the EPCS was repaired, recalibrated, and tested such that an acceptable baseline state of health was assured. Joliet and Volunteer TNT lines have been in stand-by for over four and three years respectively. As a result of application of the methods of this project, they have experienced minimal start-up and repair times and are well within the MOB readiness requirements.

Five other ammunition plants were considered. An example of current EPCS lines on a layaway status are the 5.56 mm ammunition lines at Lake City Army Ammunition Plant.



LAKE CITY ARMY AMMUNITION PLANT (LCAAP)

At Lake City, their electronic process control system consists of four functional submodules used in the manufacturing of 5.56mm ammunition. Each of the submodules are made up of five production lines with each production line being controlled by its own processor as shown in the schematic on the preceding page.

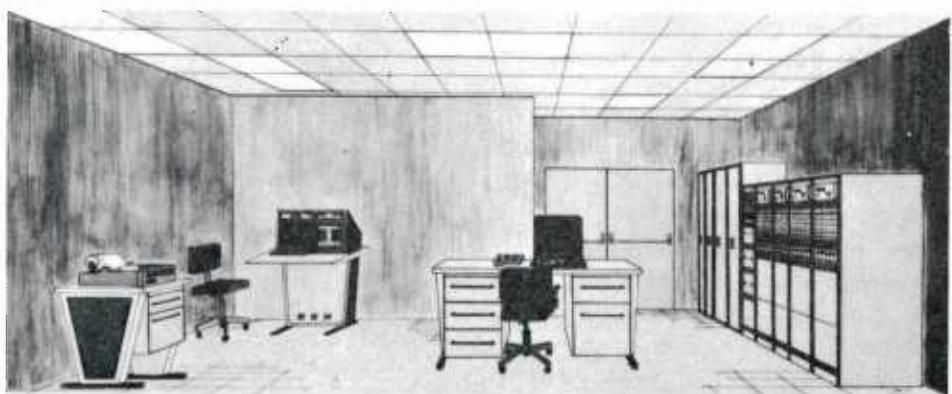
The project has developed methods which minimize mobilization times involving: baseline techniques, failure and defect reporting, user-adapted step by step procedures, cross reference methods, documentation orientation and structure, skills registers, reliability assessments, spare parts and environmental control. These methods have been directed to the Third Party Operability (TPO) concept which uses structured procedures and permits competent but unfamiliar personnel to utilize the EPSCS. This method minimizes problems associated with changes in: personnel, contractors, documentation and other sources, and improves normal operating efficiency. The method also allows for employing common procedures among all facilities promoting a corporate approach to readiness and providing a Government overview of the EPSCS's.

The success of this project has resulted in the GAO endorsing (DARCOM No. 2G816, MCH82) application of the layaway procedures to all remaining EPSCS's as well as for all newly developed EPSCS production facilities. The procedures developed in this project are being implemented under an OMNIBUS program for establishing criteria for new facilities and under project 5 82 8282 for 19 current EPSCS's which control 30 modern production lines at eight different GOCO plants.

COMPUTER CONTROLLED PRESSES

PROVIDE HIGH RELIABILITY

The press forming of high explosives has become a part of computer age technology at the Iowa Army Ammunition Plant in Middletown, Iowa. Precision explosive warheads for various anti-tank missiles and mines are being pressed using the latest in computerized process controls. The completely automatic press cycles use a process controller to monitor and control ram pressures, cycle times, and other decision making functions necessary to safely produce a precision explosive warhead. See artist's drawing of the control facility.



The Viper warhead (Project 5 78 2182) is unusual in that two warheads are pressed simultaneously on a single press. The process controller makes certain that all operations on both warheads occur at the same instant to avoid asymmetric stress on the frame of the press.

The Hellfire warhead (Projects IAAP 3-80-292 and PIF 3 81 0059) requires a punch change during the cycle. Using sensors, the controller insures that the heavy tooling is accurately located and locked into position at the proper time. All of the operations are automatic.

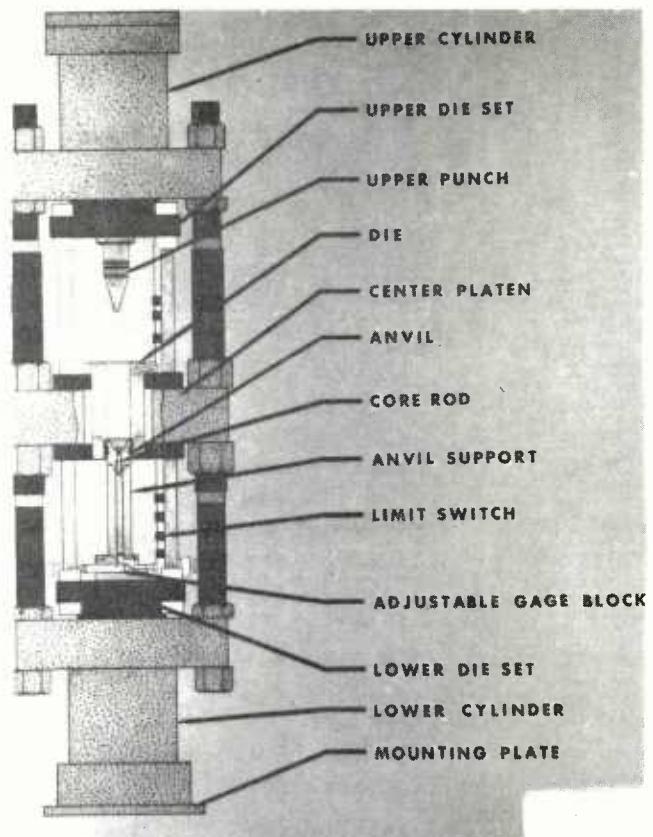
The versatility of the programmable controller is such that many safety features have been added to the operation that would have been impossible with a conventional relay panel. The controller knows and monitors what should be happening at any point within the press cycle. (See pictorial representation of the press on following page.) If a comparison with the current operation shows any discrepancy, the press is automatically shut down.

Over a period of two years, the computerized pressing of explosives has been found to be highly reliable and trouble free. To further improve reliability of the I-TOW operation, (Project 379 2158), experiments are now being conducted to test the feasibility of remote troubleshooting. Currently, the processor connected to one of the presses is being monitored at the Engineering office two miles away. Press cycle data is transmitted at 5-second intervals and analyzed to insure that the press is functioning properly. In the event of a malfunction, the reason for the trouble is readily available to the engineering group. Frequently this allows the mechanic to be dispatched to the offending operation with foreknowledge of both the problem and the likely repair procedure. Machine repair of this nature should result in a maximum of production uptime.

Future plans are to link more of the presses to a central computer. This will provide instantly available information to Management concerning such things as product output and equipment reliability.

Advanced process controllers are finding many new uses at the Iowa Army Ammunition Plant. Due to the success rate, reliability and other desirable features offered by the P.C., departments other than Production are becoming involved. High in consideration are operational safety, economics, and quality control, all enhanced by the use of this technology.

The concept of using process controllers to automate explosive operations has been with the IAAP and its operating contractor, Mason & Hanger-Silas Mason Co., Inc. for a number of years. Automated maintenance and feedback for Management is a new application for this equipment. More applications are certain to appear as time goes on. One thing is certain, process controller based equipment will be a very real part of the defense plant of the future.



I-TOW PRODUCTION PRESS

PRECISION MACHINING OF OPTICAL COMPONENTS

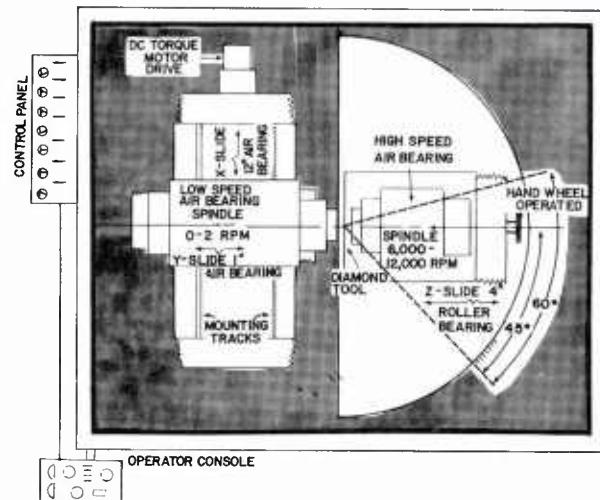
DoD has recently increased its emphasis on electro-optical and laser material programs. The optical manufacturing community, which is based primarily upon optical grinding and polishing techniques, is experiencing difficulty in maintaining a sufficient supply to meet the current demand without exceeding established cost boundaries. To resolve this problem, the military sought to advance the state of the art in single point diamond machining technology as early as 1976. Ref: MMT 3 XX 3445.

Early demonstrations proved that precision diamond machining of both metals and insulators was possible. Also, diamond machining lends itself to turning aspheric surfaces of revolution such as parabolas, ellipses, hyperbolas, et al. In addition, precision diamond machined optics has a host of advantageous features, e.g.,

- o Flexibility in design.
- o Faster alignment and centration.
- o Mechanical stability.
- o Good thermal stability.
- o Flexibility in material selection
- o No degrading edge effects.
- o Resistance to corrosion
- o Inexpensive to refurbish.

Diamond machining is currently compatible with many materials including aluminum, copper, brass, acrylic plastic, and other substrate material such as beryllium or stainless steel.

Recently, a demonstration was performed at the Kollmorgen Corp., Intop Division, to demonstrate and display the latest developments in manufacturing technology in optics. During the demonstration, the MICOM funded computerized diamond turning equipment displayed its ability to fabricate precision aspheric optics with various materials and test them. However, materials such as glass and steel are still unable to be machined using this approach.



COMPUTERIZED MATERIAL

PROPERTIES DATA (UPDATE)

The adaptation of computer technology to material properties data, used principally for the evaluation and selection of materials, is being advanced at the US Army Armaments Research and Development Command (ARRADCOM). Programs, having remote data access capability, are being developed by the Plastics Technical Evaluation Center (PLASTEC), Ref: MMT project 5 76 4456, to serve a wide variety of Army and other service needs. This PLASTEC activity represents an independent part of CAD/CAM programs underway within the Army.

Located in Dover, NJ, PLASTEC is chartered with the responsibility to collect, analyze, store, and disseminate technical information for plastic materials to the military, other Government agencies, and industry.

Traditionally, material property data have been obtained by acquiring an assortment of handbooks and other literature references. Although this procedure has been optimized by computer access to bibliographic data listings, the acquisition and review of each reference is time consuming but necessary to ascertain data relevancy. PLASTEC recognized the advantages and need for direct access to numeric data contained in these reports and has begun to computerize the data.

To resolve this problem, PLASTEC conducted surveys and the results suggested the need for a computerized numeric data bank for properties and also a need for a data-management system having sophisticated capabilities. These include tutorial access, varied search strategies, data manipulation, plot capability, and output in text form. PLASTEC has acquired such a system to meet its current and future needs.

PLASTEC's initial thrust in computerized data began with a compatibility program, written in Fortran. Designated COMPAT, it contains technical data describing the interaction of plastics, elastomers, and adhesives in combination with such energetic materials; i.e., explosives, propellants and pyrotechnics. Since COMPAT's inception, PLASTEC's acquired data management system has been the basis for the current PLASTEC programs as described in the following paragraph.

COMPAT, the first PLASTEC program, is the most comprehensive repository of compatibility data of this type in the free world. The COMPAT program, commercially marketed by PLASTEC, provided insight into the treatment of numeric data. It pointed out that a centralized computerized data source was valuable to product assessments and that those heretofore not familiar with computer technology could readily gain access to the data. PLASTEC is continuing to pursue COMPAT and the generation of other data banks for plastic materials. Currently, two major efforts are being considered, the first dealing with environmental effects or permanence properties, and the second with the basic plastic material properties.

The permanence properties program is now under development and deals with laboratory data for the environmental effects on plastics. The environments include chemicals, the atmosphere, temperature, and stress. The program, although still in its infancy, will allow direct data retrieval and material selection. As the program exists, the user is able to select the environment of interest and enter the material name to obtain available technical data or select the material suitable in the environment. The program will incorporate a sophisticated, automated dialogue mode of operation.

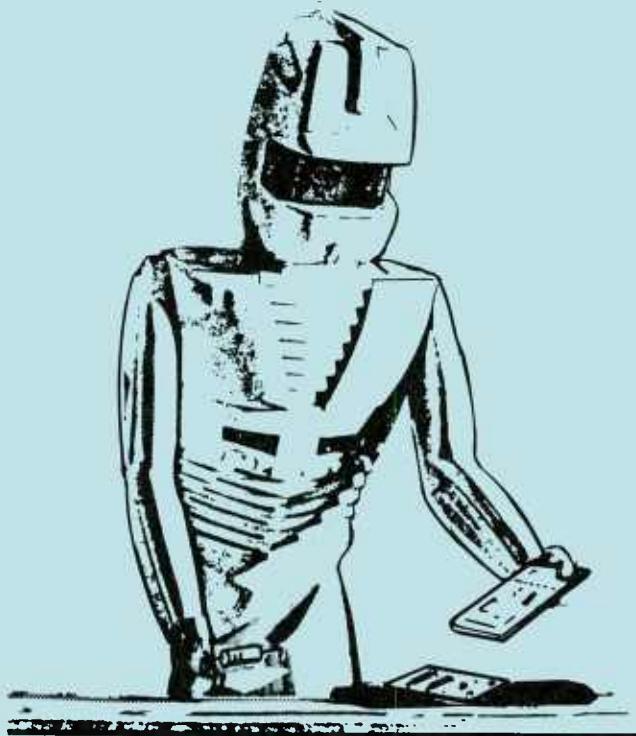
A plastics-properties program has also been proposed, it will be, by far, the most important and complex. This program is complex because the data is engineering-oriented. The properties are to include mechanical, thermal, electrical, optical, and physical. At present, program development is hindered both by lack of funding and the lack of adequate engineering data. This program is challenging and is necessary to meet future needs. The next generation of designers and engineers will be trained in the use of computers and expect to find an organized body of materials data available for their use.

Additional PLASTEC programs in development deal with (1) trade name designations and descriptions of polymeric materials and (2) a file directory of plastic specialists in the Government.

700 ASSEMBLY

**DEVELOPMENT METHOD FOR CONSOLIDATION & AUTO ASSY
OF SMALL MINES**

700 ASSEMBLY



The integration of computer aided technology into assembly operations is illustrated by the use of robotics in assembly of printed circuit boards as shown. Factors typically considered in assembly range from aids for planning, simulation and design to totally automatic machines which perform assembly. The increased use of robots in assembly introduces the need for improved programming languages, hierarchical control, end effectors and tools, sensing systems and machine intelligence.

DEVELOPMENT METHOD OF CONSOLIDATION AND AUTOMATIC ASSEMBLY OF AMMUNITION PRODUCTION LINES

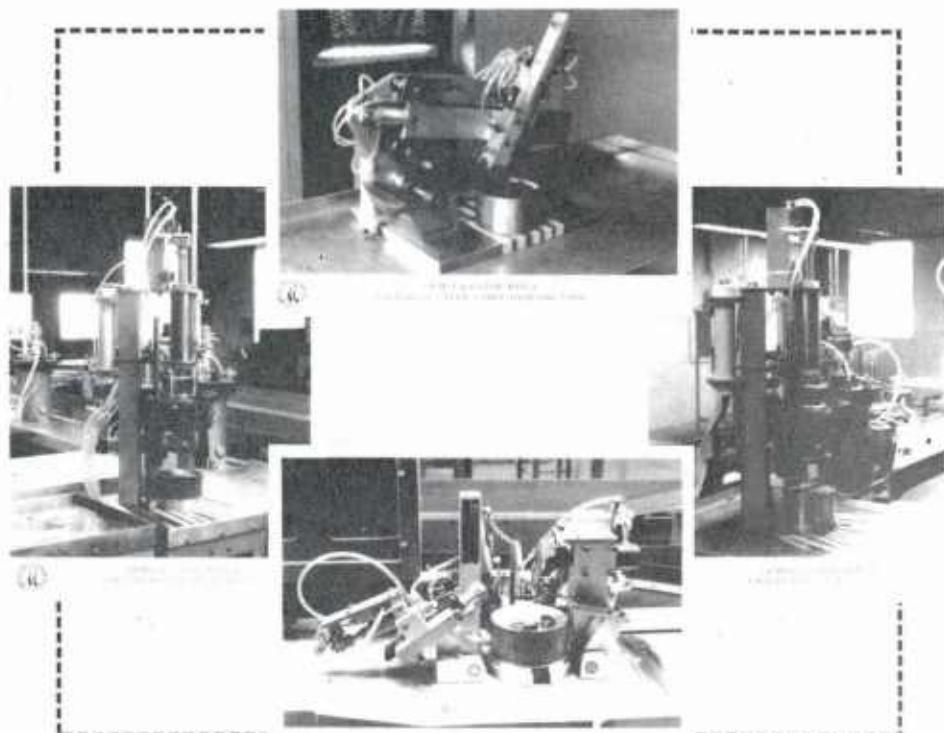
Small mines are relatively new Army items. They require first generation mechanized assembly equipment to meet planned mobilization requirements, off-line operations and on-line inspections. Multiple handling is required for the predominately manual Load, Assemble and Pack (LAP) operations which are labor intensive, hazardous, and lack repeatability creating numerous production problems.

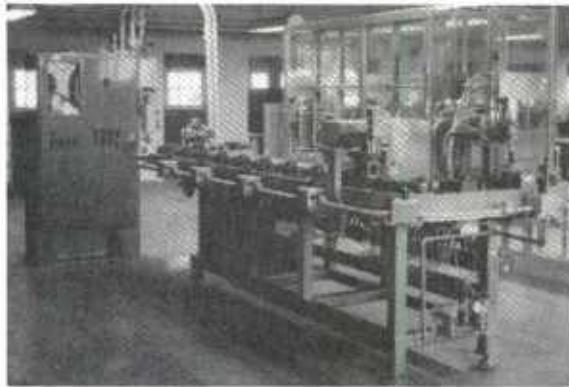
To remedy this problem, ARRADCOM (Ref: MMT 5 79 4498, entitled "Development Method for Consolidation & Auto Assy of Small Mines" conducted a study to determine the extent of possible automation for each operation on three mine systems (RAAM, GEMSS, and GATOR) being produced at Iowa Army Ammunition Plant (IAAP).

The results of this study revealed that complete automation of the production lines is not economically feasible at this time. However, a multi-task project was initiated to develop (a) assembly aid fixtures, (b) an automatic soldering machine, and (c) a computerized electronics tester to assist in the production of the GEMSS and GATOR mines.

This project accomplished the following:

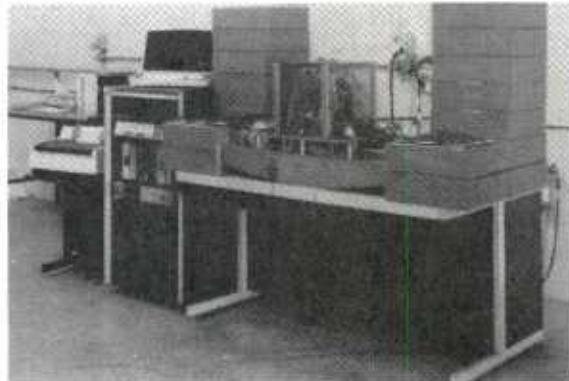
Task 01 - Assembly Aid Fixtures for the GEMSS & GATOR Mines. Four fixtures were designed and tested to rotate the main charge and to disperse adhesive, bend the MDF lead of the Safety Arming Assembly (S&A), also rotate the mine case to disperse adhesive and cut the flexible cable.





GEMSS GATOR
AUTOMATIC SOLDERING & INSPECTION MACHINE

Task 02 - Automatic Solder Machine. This task designed and built a machine to automate the soldering of all points simultaneously of the Safety & Arming (S&A) assembly flexible cable to the electronics assembly, and automatically inspect the resistance of the S&A circuits as well as the MCD (Magnetic Coupling Device) circuit of the electronics assembly. The machine can be adjusted to each of two mine types, GEMSS & GATOR.



RAAM GEMSS GATOR
ELECTRICAL TESTER

Task 03 - Computerized Electronics Tester for the RAAM, GEMSS, & GATOR Mines. An electronic test set was designed and built by Computer Automation to check individual non-activation cell voltage, to verify shorts across the firing capacitor, to verify shorts in series with electronic battery primer (EBI), and to verify anti-personnel (AP) mine trip line continuity.

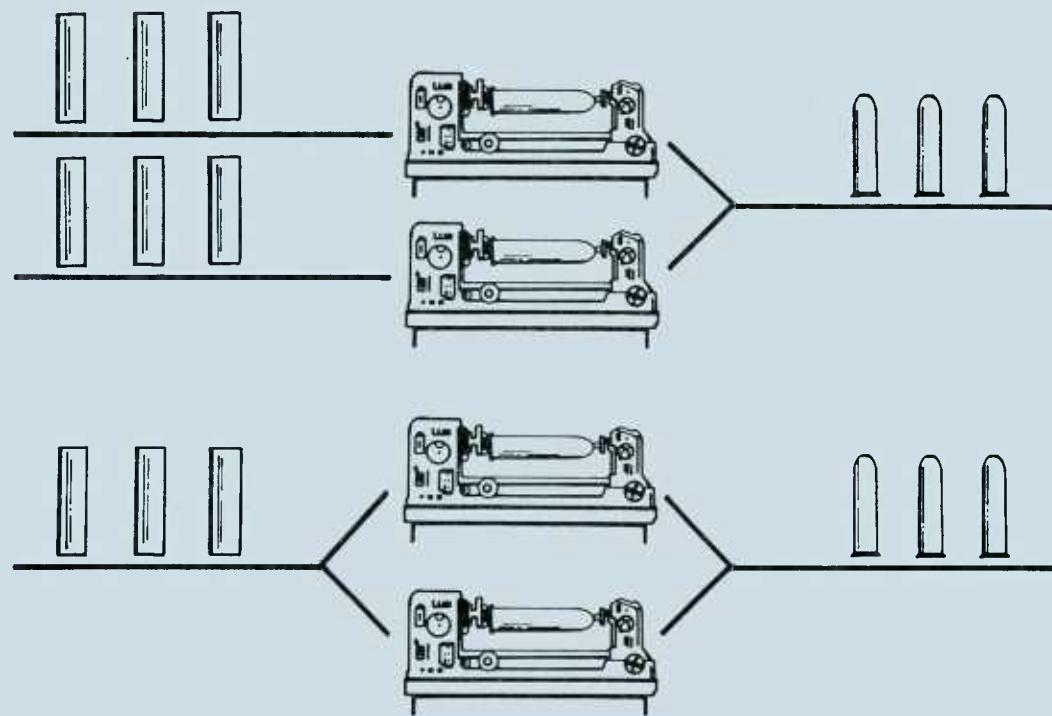
At present, Tasks 01, 02, and 03 have been implemented under IPF project 5 78 4869 entitled "GEMSS IPF" for the GEMSS line. Future implementation will occur for the GATOR line under IPF project 5 83 4871 entitled "GATOR IPF" yet to be funded. Also at a future time, the equipment will be implemented at Lone Star Ammunition Plant under an FY84 "GATOR" expansion project.

800 SIMULATION, MODELING & OPERATION RESEARCH

SIMULATION OF AMMUNITION PRODUCTION LINES

ACCEPTANCE CRITERIA FOR CONTINUOUS SINGLE BASE PROPELLANT

800 SIMULATION, MODELING & OPERATIONS RESEARCH



Simulation, modeling, and operations research is the soft technology for optimizing manufacturing systems. The modeling of one manufacturing operation is illustrated. An analysis of the reliability of machine tools and handling equipment would be included in an evaluation of an operation.

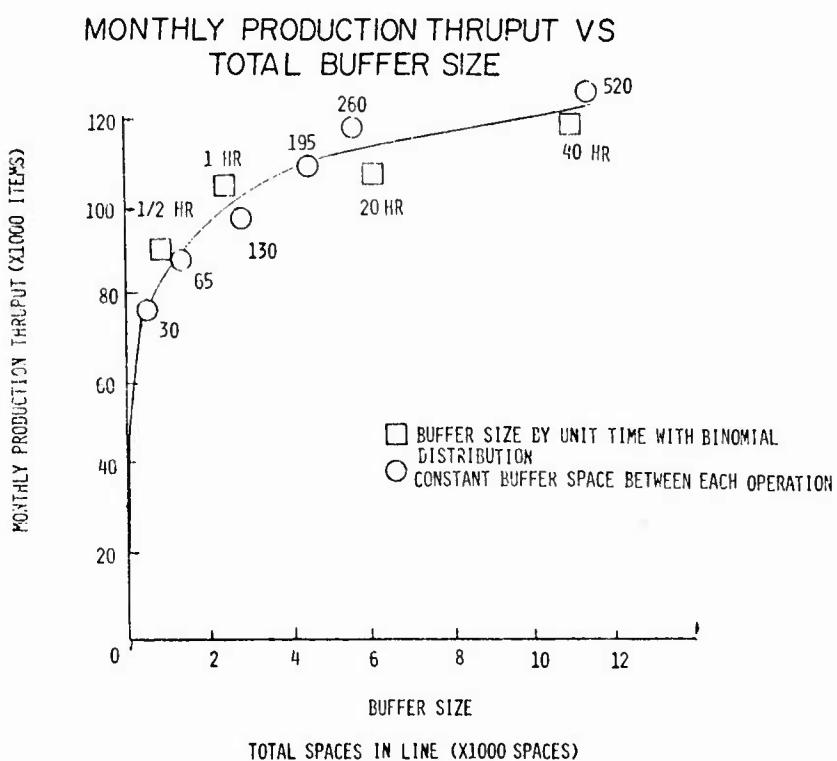
SIMULATION OF AMMUNITION PRODUCTION LINES

The modernization and expansion of artillery ammunition manufacturing plants to meet scheduled production rates must take into account more than just the nominal cycle times of individual components. Methods are needed for designing production lines operating in a real environment and subject to the uncertainties associated with machine break downs and scheduled maintenance.

The objective of this project (Ref: 5 79 6682) was to develop and apply simulations as an aid in system design of modern metal parts production lines.

The General Modeling System (GENMOD) was developed in response to a need to model various automated production lines to study the effects of proposed design changes.

As a result of establishing the generic methodology (GENMOD) a key finding was the validity of using the binomial distribution to predict the buffer size of material handling equipment. The buffer size applies between operations for the entire sequence of operations in a production line. A relationship between buffer size and monthly production rate is illustrated in the figure below.



Examples of how this program has been applied are summarized below:

● Norris Industries M483 parts line:

Data was collected during prove-out of line (June, 1979) and used in GENMOD model. The results revealed there was an excellent correlation between actual and predicted production rates. An analysis of the simulation results showed several areas of over and under production that would cause imbalances in the line. Also, during the prove-out one machine was removed from an operation and buffering was made available in another due in part to the data provided by the computer simulation.

● Mississippi Army Ammo Plant:

Using the Norris Industries prove-out data the entire metal parts line was simulated. Various runs testing buffering sensitivities lead to setting buffering requirements at 130/operation in order to meet designed rate. With the aid of the GENMOD computer simulation an overall expected buffering capacity was established for the entire material handling system.

● Louisiana Army Ammo Plant:

GENMOD has been used at LAAP to simulate several existing and proposed production lines. Recently, the 155mm M483Al metal parts production line was simulated. Three separate models were used. The first model included the production of the projectile body. Two smaller models were used for simulating the manufacturing of bases and ogives for the projectile metal parts.

Block diagrams were developed first, showing the flow process throughout the manufacturing facilities. Machines were coded by type. The operational parameters were assigned to each building block based on RAM data collected over the past year and engineering estimates. Buffers were seeded with approximately half of capacity. This capacity was based on actual available space.

After the models were completed, the computer was used to run the simulations. The times of the simulation were chosen to be 500 continuous hours, but any times could have been used.

Results showed expected outputs for several time frames, including a 3-8-5, 63 shift month. Bottleneck operations were easily identified.

Other possibilities include changing the number of machines found in the bottleneck operations, changing buffer capacities, using the latest production and defect rates, etc., and running the simulation over.

The GENMOD simulation has proved to be a valuable asset to LAAP, as it is not difficult to use and provides the user with a variety of options to use in simulating production lines.

ACCEPTANCE CRITERIA

FOR CONTINUOUS SINGLE BASE PROPELLANT

In the early 1970's, the military authorized a project to establish non-ballistic acceptance and homogeneity limits for M1 propellants (e.g. M1MP f/105, M1SP f/105 propellant charge) other than those evaluated by an earlier MMT project.

The objective of this MMT project (MMT 5-76/77T 4302 titled "Acceptance Criteria for Single Base Propellants") were as follows:

- o To establish reliable determinations of cause/effect as related to propellant manufacture.
- o To develop new test methods, sampling and testing procedures compatible with the continuous process.
- o To judiciously select propellant parameters for control and testing to allow propellant acceptance without gun testing.

This project permitted reliable determination of cause and effect relationship between propellant processing and propellant performance for M1 propellants. The net results of this project are summarized as follows:

- o Two additional testing techniques have been successfully developed for rapid determination and control of product parameters that influence the quality and measure the stability of finished products.
- o Computerized test techniques were developed, e.g. image analyzer technology, which will allow rapid retrieval of test data for use in the continuous evaluation and control of propellants produced by the CASBL.
- o An investigation revealed that the die pin sizes (perforation diameters), propellant densities, propellant plasticizer, and NC content had significant influence on the quality of finished propellant which is detectable in weapon performance.

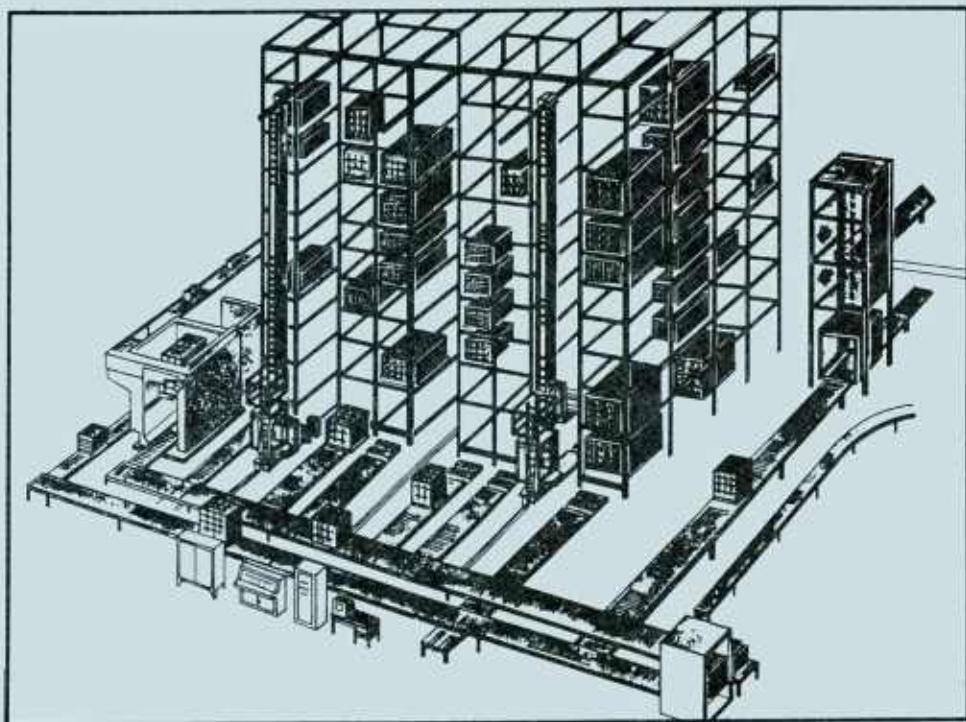
In summary, the expected savings as a result of changing the testing and quality assurance programs presently being used for the batch method to the new techniques and QA plan used for the continuous process can save \$60,000 per year based on an annual production of 2.4 million pounds of M1 propellant.

900 MATERIALS HANDLING AND STORAGE

STACKER CRANE



900 MATERIALS HANDLING AND STORAGE



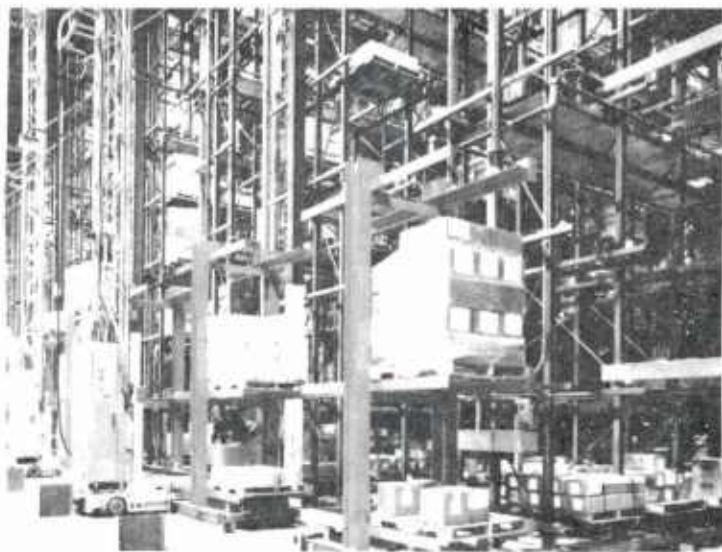
This area involves the integration of computer aided technology to aid in material handling. Objectives here include complying with OSHA and EPA standards and reducing costs and materials handling time. An automated material storage, handling and retrieval system is illustrated.

Robots provide the most flexible form of automation for parts and material handling, fabrication and assembly tasks and programmable robots may be reprogrammed to perform various tasks as required by changing workload demand and product mix.

AUTOMATIC STORAGE AND RETRIEVAL SYSTEM

STACKER CRANE

A \$1.4 million contract was awarded to construct and install a new computerized controlled stacker storage facility, or automated warehouse, to be housed in one of the newly constructed buildings under Watervliet's REARM (Ref: PIF 6 81 8015) program. The pictorial illustration below is a typical automatic storage and retrieval system.



The system to be installed at Watervliet is unique because of the "double deep" feature. That means that when the computer is asked to retrieve a pallet from the inside bin, the one away from the aisle, the automated crane in the aisle will go to the right location, remove the outside pallet and store it elsewhere. The crane will then return to the proper location, reach through the now empty outer bin to the desired inner one, remove it and deliver it to the requestor via the conveyors.

When the material is delivered onto an input conveyor spur, the material is automatically weighed and sized. If unacceptable, it will be transferred by the computer to a reject operator for correction. If acceptable, the material will move on a conveyor to an input operator where the drawing number, along with the applicable information, will be recorded in the computer for each item on the pallet.

The computer will then take a charge, decide which aisle the items should go in, and place the pallet on the proper input conveyor from which the aisle crane will lift it and put it in an empty bin. The locations are chosen solely by their drawing number entered in the computer memory.

This facility, now completed, will be used to store 105mm breech rings and associated components.

1000 TEST, INSPECTION AND EVALUATION

OPTICAL INSPECTION OF PRINTED CIRCUIT BOARDS & COMPONENTS

GUN TUBE PROFILE INSPECTION SYSTEM

LOW COST, HIGH VOLUME RADIOPHASIC INSPECTION

COMPUTER-AIDED HOLOGRAPHIC COMPOSITES INSPECTION

AUTOMATIC X-RAY INSPECTION SYSTEM

HOT FORGING WALL VARIATION MEASUREMENT

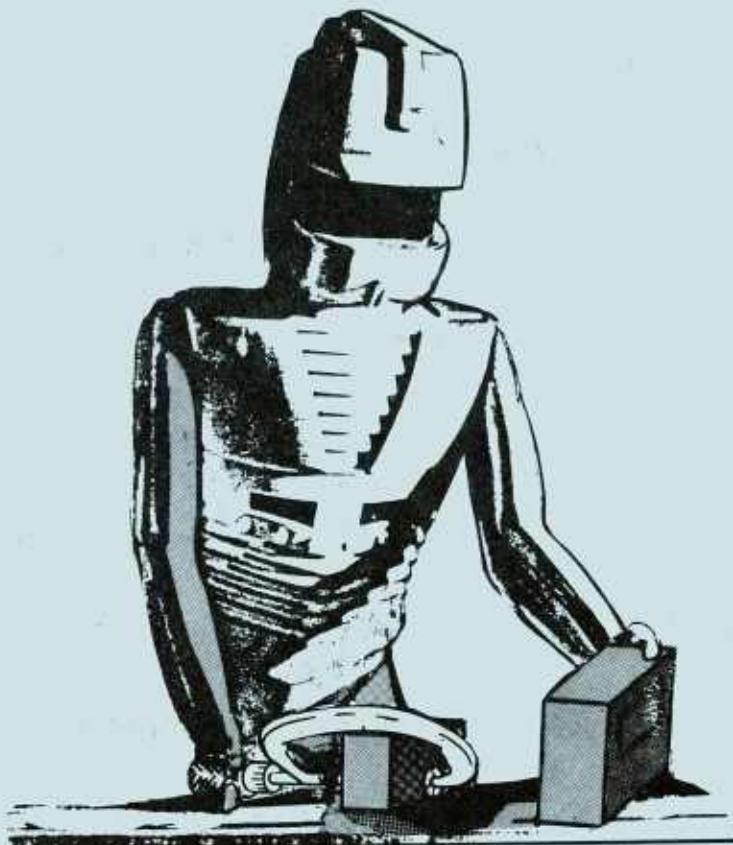
AIR DEFENSE MISSILE FUSE COMPUTERIZED MODAL TESTING

ULTRASONIC TRANSDUCER CALIBRATION EQUIPMENT

AUTOMATIC IN-PROCESS MICROCIRCUIT EVALUATION

AUTOMATIC INSPECTION DEVICE FOR EXPLOSIVE CHARGE IN SHELL

1000 TEST, INSPECTION AND EVALUATION



This thrust area develops and transitions real time, computerized, nondestructive testing techniques for use in fabrication and assembly operations. Emphasis is put on automatic, in-process inspection and decision making without human intervention. The concept is illustrated by the use of a robot.

OPTICAL INSPECTION OF PRINTED CIRCUIT BOARDS AND COMPONENTS

Inspection cost of several major missile systems (e.g., HELLFIRE, Pershing II, SAM-D, and SPRINT) have soared during the production phase due in part to the time-consuming task of inspecting printed circuit board (PCB) assemblies. Prior to this effort, the Government and commercial industry normally inspected these assemblies visually. This proved to be very tedious, inefficient, and costly when the production quantities were extremely large. To solve this problem, a reliable, low-cost automated inspection system was needed to detect common defects such as: excess solder, lack of solder, solder bridges, improper lead cutting and bending, and missing or incorrectly oriented parts. Prior effort in this area was performed under Project 377 3169 titled, "Automatic Optical Inspection of Printed Circuit Boards and Components (CAM)," of which this project is a continuation. A prototype system was developed under the prior effort.

The objective of this effort was to develop an automated inspection system with operating procedures which could detect the majority of problems encountered in PCB manufacturing.

The prototype system that was developed consisted of a very low power helium neon laser, an X-Y moving galvanometer scanner, and several folding mirrors. When the laser scanner is operating, it scans a preprogrammed path over the lead side of a PCB. While scanning the board, a unique shadow signature is detected by the silicon photo diodes located at the optimum geometry, see Figures 1 and 2. This signal is processed and evaluated by a minicomputer to determine whether the components are as specified.

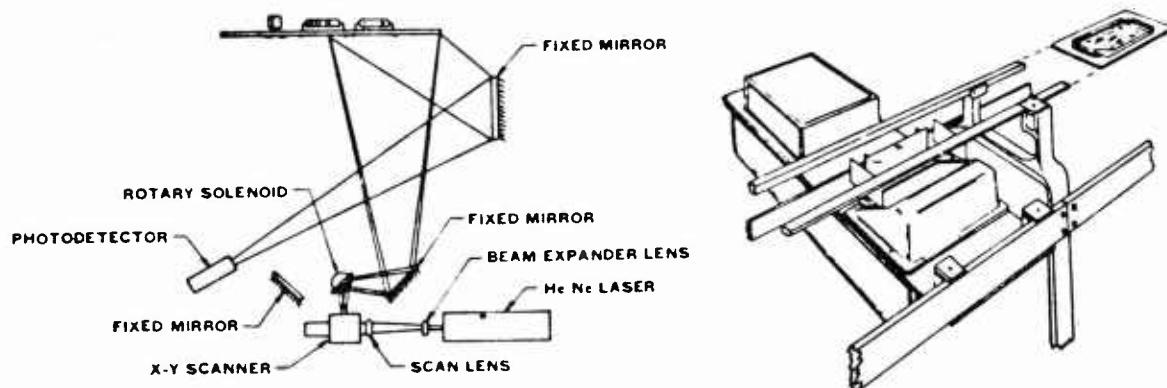


Figure 1 - Scanner Optical Path

Figure 2 - On Line Scanner Configuration

To prove out the developed scanner system, the prototype was incorporated as an integral part of three production lines with the intention of demonstrating its capability to function in various production environments. As a result of the initial demonstration, the inspection scanner

system proved that it can be used to simultaneously detect major defects, such as solder bridges and missing components, thus expediting the examination of PCBs. The system demonstrated is capable of functioning at any point in the production process where the maximum cost benefit can be realized.

The instruments comprising the PCB inspection system are designed to automatically inspect bare and/or populated PCB for defects. As a preventive measure, the system is capable of supplying feedback information which potentially prohibits the manufacturing and/or transfer to faulty assemblies. The system, in addition to all other features mentioned, has automatic sorting capabilities. Also, resulting from the demonstration, the system proved that it was capable of inspecting PCBs having approximately 60 components in 2-1/2 seconds where the production rate was established to be 20 boards per minute. For a production illustration of the initial demonstration, refer to Figure 3.

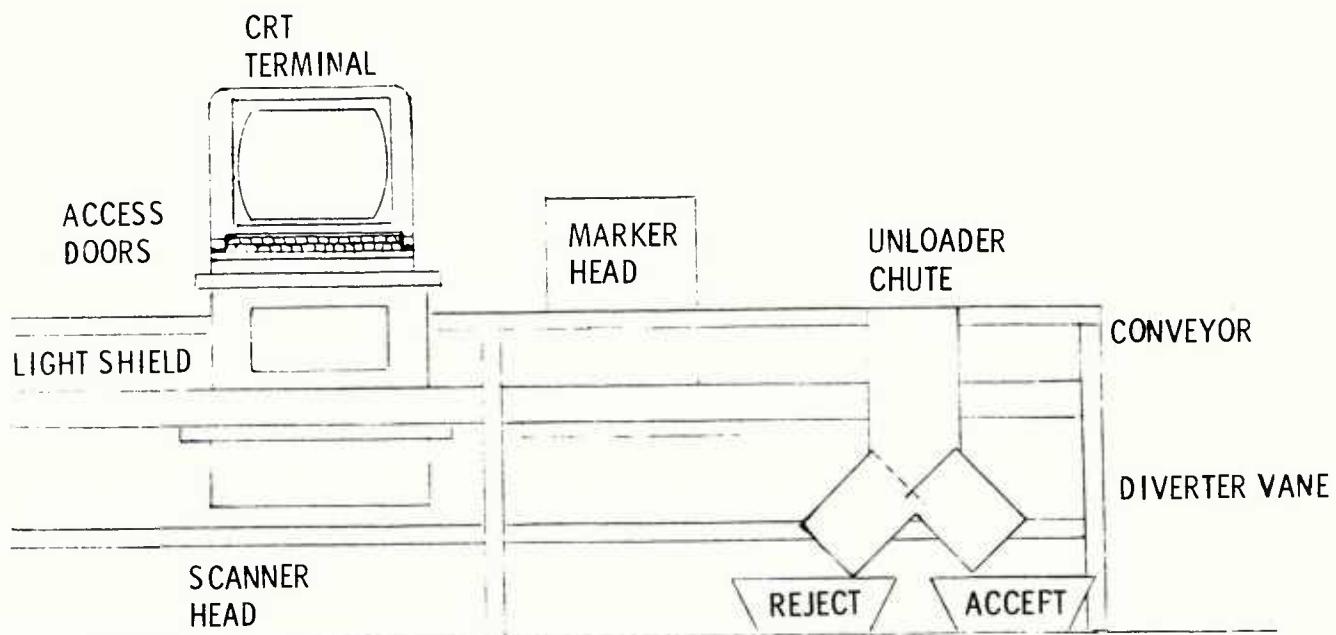


Figure 3. USM Line installation

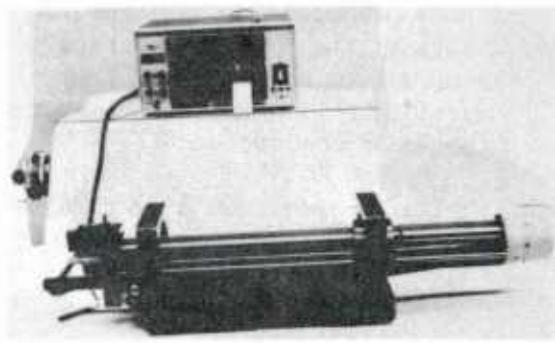
A value analysis of the inspection system indicated that, while the system will meet all the objectives, the optimum area of use is for final visual inspection of a high-speed automated assembly line, to determine insertion quality. The system is above 99% effective at finding programmed defects. These defects include misoriented leads, missing leads, and leads clipped too short. The payback time for this system is estimated to be 18 months. In addition Chrysler, Huntsville Electronics Division, plans to manufacture and market the system commercially.

GUN TUBE PROFILE INSPECTION SYSTEM

Watervliet Arsenal has recently developed a Gun Tube Profile Inspection System (M 77 6350-2028 to inspect various intersecting tapered and cylindrical areas. It is critical that these dimensions be accurate as out of tolerance dimensions cause lack of obturation, difficulties with chambering the ammunition, and case extractions.

The system consists of two units, an electronic control, data processing console and a cannon chamber gage. The cannon chamber gage contains a master tool steel template scaled 1:1 to longitudinal cross section profile. Two radially opposed position sensors (LVDT's) measure the difference in a cross sectional diametrical plane between the master template and the chamber being inspected. A linear scale senses the down chamber location of the position sensors with respect to the rear face of the tube. The linear scale consists of a glass incremental grating scale and a traveling head. The reading head transmits light from a miniature filament lamp, through the optical grating scale, to two pair of photodetectors on the opposite side. As the head moves, it generates two signals, each of which is a close approximation of a sine wave. One signal train is displaced 90° in phase with respect to the other. This permits detection of direction of travel. The electronic control, data processing console presents a continuous display of the output of each LVDT with .0001 inch resolution. All displays can be independently switched from customary units (inches) to metric units. The continuous display of downbore distance has .0001 inch resolution. The displayed LVDT values and the downbore distance values can be printed upon command.

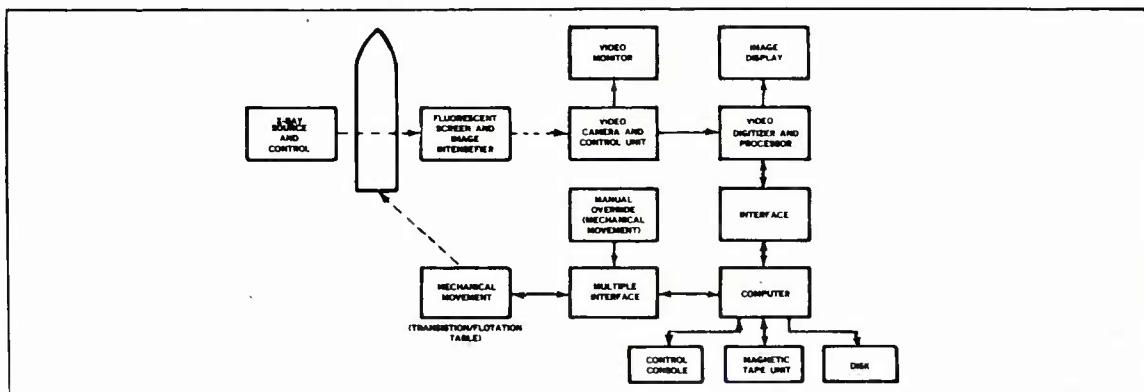
This system is in the process of being implemented on the 105mm M68 Gun Tube production line at Watervliet Arsenal, Watervliet, NY.



LOW COST, HIGH VOLUME RADIOGRAPHIC INSPECTION

Data collected at MICOM indicates that extensive radiographic inspection is employed in assuring the quality of missile components and assemblies. For example, X-ray inspection of the Roland missile propulsion assembly requires in excess of four man hours to complete. Proposed production rates of up to 100 missiles per month would require three X-ray technicians and three conventional X-ray inspection stations to maintain the required through put for the propulsion assembly alone. Using traditional radiographic, film based, examination of components and assemblies, it has been determined to be economically unacceptable for high rate production.

The purpose of this project (Ref: MMT 3 78 3454) was to develop a non-film radiographic inspection system for high volume production. This project produced a prototype non-film X-ray system for the inspection of complex parts and assemblies produced at a high rate. This system features real-time X-ray, digital image enhancement, remote part positioning, and automatic computer aided operations.



The part to be inspected is mounted on a remotely-controlled translation/rotation stage. X-rays from the source pass through the object to form a visible image on the fluorescent screen. The image, brightened by the image intensifier, is detected by the video camera and displayed on a remote monitor. The image can also be digitized, enhanced in a digital image processor, and stored on a magnetic tape or disk.

Computer-aided inspection can be performed with automatic control of part positioning and image processing. The automatic computer-aided inspection scheme is cost effective when a computer is required for management and image processing for a high volume production rate.

The Roland missile final assembly inspection was chosen for the implementation of this technology. A potential cost reduction of 8:1 and time reduction of 5:1 is anticipated. Likely areas for extension of this new technique includes the inspection of castings, welds, and composites. Because of the potential cost benefits, further development could lead to the elimination of most film based radiography.

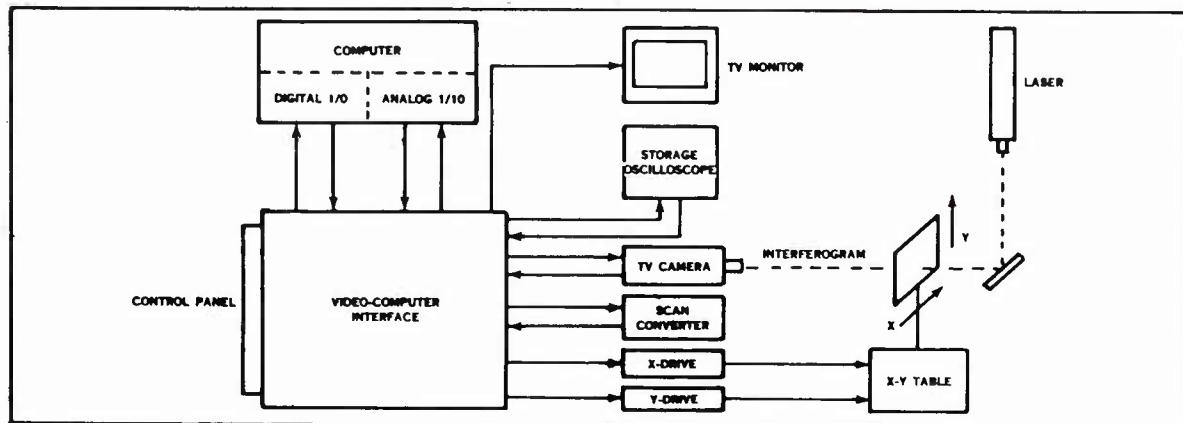
COMPUTER-AIDED

HOLOGRAPHIC COMPOSITES INSPECTION

Motor cases and other structural assemblies made of composite material used in the shoulder fired weapon systems presently do not require 100% inspection. These systems containing composite structures, if defective and undetected, could cause serious injury or death to the user.

The proposed solution was to develop a computer aided video recording system for a 100% in line holographic inspection system for composite structures. The speckle holographic technique is the only procedure having extreme sensitivity that can be adopted, along with other optical methods to quantify the magnitude of flaws and voids in composite materials.

This MMT effort (Ref: MMT R-77-3145) sponsored by MICOM evaluated a prototype system for composite structure inspection. Three different types of flaws were investigated using double exposure optical holography, shearing speckle interferometry and Young's Fringe methods. The theory for each technique and photographs of the fringe patterns are presented. The fringe density plots were made by manual and computer methods, and the flaw sizes were determined. The displacements and strains were computed.



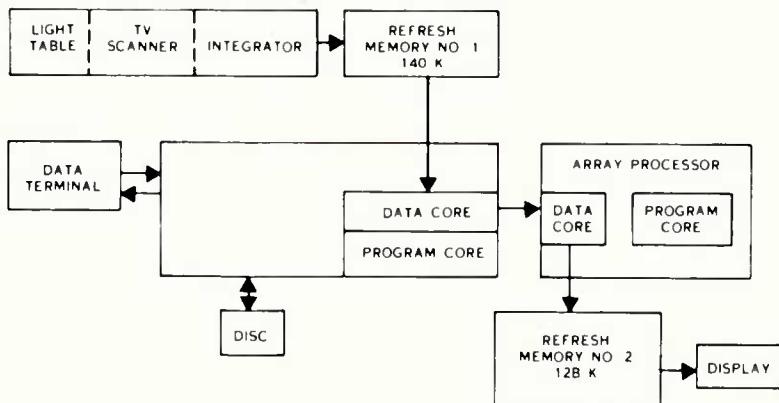
The results show that flaws in their fiber reinforced composite structures can be detected and the size determined either by optical holographic, shearing speckle, or single beam speckle interferometric techniques.

A complete nondestructive testing system to detect, locate, size, and quantify flaws in fiber reinforced composite missile launch tubes and motor cases was designed including the hardware and software. The system was assembled, interfaced, checked, and validated. Complete documentation on the system components are presented or referenced.

The system as presented utilizes the shearing speckle techniques to determine if a flaw exists in the launch tube. If so, it indicates the region where the flaw is located. The point-by-point method of Young's Fringes is used to determine the surface strain in the region of the flaw and if the item should be accepted or rejected.

AUTOMATIC X-RAY INSPECTION SYSTEM

The objective of the Automatic X-ray Inspection System (AXIS) (Ref: 5 78 4454-2 is to be capable of automatically examining film radiographics of high explosive shells and making accept/reject decisions based on the presence or absence of certain classes of defects in the explosive region of the shell. Among these defects classes are small and large cavities, cracks, pipes, annular rings, et al. This system employs the latest Computervision and image understanding technology. AXIS recognizes the defects in much the same way a human does - as deviations from smooth or average brightness variations on the image. This is in sharp contrast to previous attempts to computerize inspection employing a point-by-point comparison with an ideal template. This system has demonstrated the capability to examine one shell every ten seconds. The AXIS technology promises to have application to a variety of robot vision tasks in both manufacturing and inspection. See the pictorial block diagram of the inspection system below.

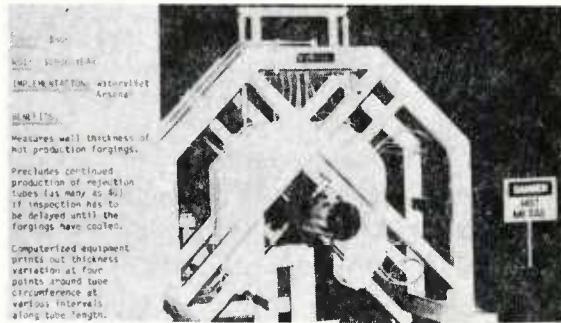


The system is in the final development stages and is undergoing preliminary testing and software optimization at Lockheed Missile and Space Company's Palo Alto Research Laboratory. The system is scheduled to be delivered to ARRADCOM in May 1982 where the system will be placed in a semi-production environment. Correlation studies will be conducted comparing human and AXIS film reading. These studies will be used to further refine the system's computer software programs. Upon completion of the software program refinements, the system will be installed at the Milan AAP where the system prove-out will continue.

HOT FORGING WALL VARIATION MEASUREMENT

With the introduction of the cannon tube rotary forge process at Watervliet Arsenal, a new line of wall thickness inspection equipment was required. The increased rotary forge production rate required the cannon tube to be inspected in the "as-forged condition" or hot. If this inspection was delayed until the forgings cooled, as many as 40 out of tolerance tubes could be produced during this cooling period.

An Ultrasonic Hot Forging Wall Variation Measurement System was developed under MMT M 76 6350-1831 and is currently in the process of being implemented at Watervliet. This ultrasonic system uses hydraulic pressure to couple the high temperature ultrasonic transducers with the hot forging. The wall thickness measurements are taken simultaneously at four positions on the gun tube circumference and the results are displayed on a computer printout. This system enables production personnel to closely monitor the forging wall thickness on a timely basis, thus eliminating the production of defective gun tubes. Savings of \$180,000 per year are anticipated. This system is currently being used to inspect 105mm M68 cannon tubes at Watervliet Arsenal.



AIR DEFENSE MISSILE FUZE COMPUTERIZED MODAL TESTING

Recently Harry Diamond Laboratories (HDL) developed a computerized modal testing system (Ref: MMT M 6350-2037) utilizing a digital minicomputer with on-line monitoring capabilities. This system is intended to replace the current manual resonant vibration simulation testing which is extremely complex and often produces unreliable results. This modal tester has the capability to simulate known field vibration and evaluate the vibration modes (5-10,000, Hz range) and dynamic behavior of the fuze. Also, the tester has the capability to automatically correct frequencies which insures dwell resonant frequency for a specified duration.

This test equipment has been used by HDL to establish the computerized modal test procedures for the PATRIOT fuze. The tester will be demonstrated to the PATRIOT and MLRS project office for production acceptance applications.

ULTRASONIC TRANSDUCER CALIBRATION EQUIPMENT

AMMRC has recently acquired an Ultrasonic Transducer Calibration capability for checking and characterizing ultrasonic transducers used in research and industrial NDT. This calibration equipment interfaces with a computer that displays the transducer's radiation pattern and records the absolute radiation intensity at any point in the output. The frequency range of this calibration equipment is 1-25 MHz. In the near future, Ammrc will be in the position to offer an Ultrasonic Transducer calibration service to DARCOM installations. This project (Ref: MMT M 79 6350-2410) was established because ultrasonic transducers continue to be one of the greatest weaknesses in ultrasonic NDT technology. The construction of transducers has been something of a black art in the past, and transducers are highly susceptible to damage and deterioration.



MICROCIRCUIT EVALUATION AUTOMATIC IN-PROCESS

The AIME system (Ref: MMT 2 77-9808) was developed to perform high speed 100% inspection of substrate thick film conductor lines and insulator areas. The system has the capability to inspect substrates at the rate of approximately 750 per hour. AIME uses a high resolution Return Beam Vidicon (RBV) camera tube and computer control to scan a 2 x 2 inch substrate. The RBV is operated with computer controlled electronic steering and zoom to provide an appropriate level of detail for rapid sequential frame inspection. Video from each frame is compared with a referenced image stored on a video disc. Differences are displayed on a color TV monitor and processed by the computer to identify and characterize faults; opens, shorts, voids, smears. These faults are displayed on the TV monitor as a red image and extra widths are displayed as a green image. The system is basically completed. Only a few design improvements remain to be incorporated. A project demonstration was held at RCA 12 June 1980.

AUTOMATIC INSPECTION DEVICE FOR EXPLOSIVE CHANGE IN SHELL (AIDECS)

The AIDECS system, (Ref: MMT 5 78 4454-1) when completed, will be completely automated with an automatic computer controlled materiel handling system and automatic computer analysis which accepts or rejects the shell. This system uses the Compton Scattering technique where a narrow beam of gamma rays are emitted through the high explosive charge of an artillery projectile. Every point along the beam emits radiation whose intensity is directly related to the amount of mass at that point. By monitoring the scattered radiation, the AIDECS system can automatically detect voids and low density area defects.

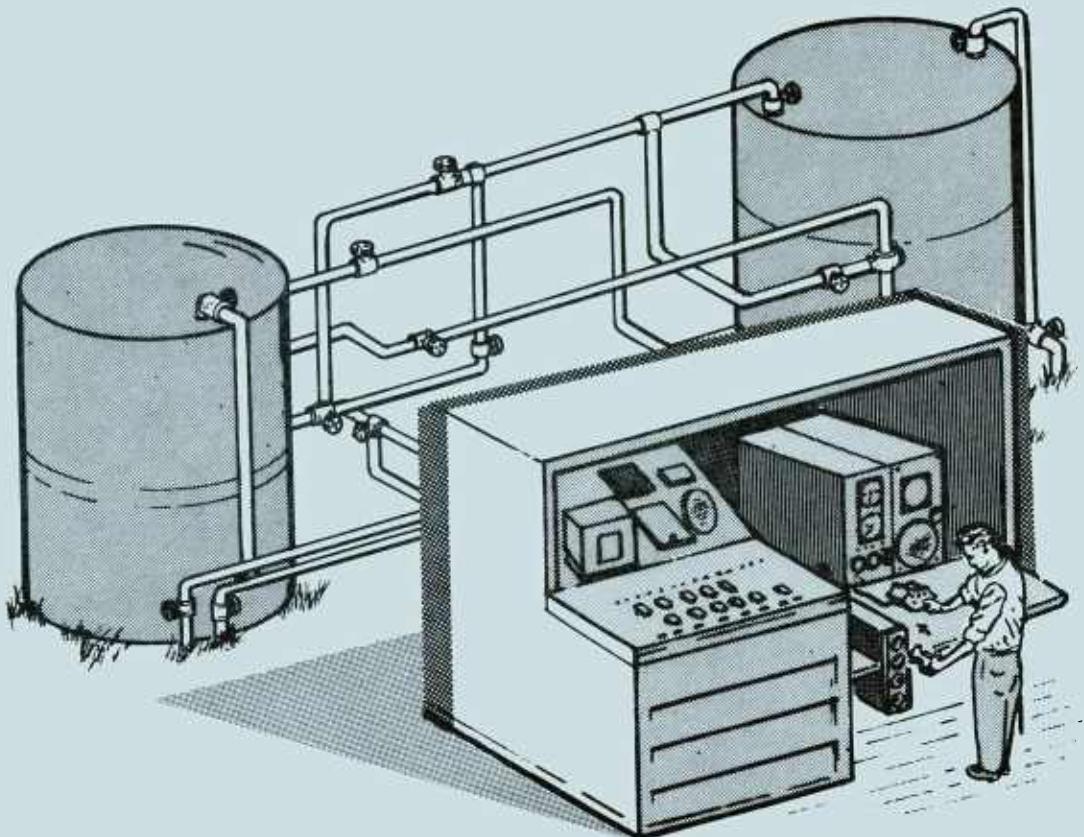
With the engineering model (designed for inspection of the 105MM, M1 Projectile) installed at ARRADCOM and proven-out on inert standards, live shells were introduced into the unit. The results of these tests showed that there was no difference in response between the inert standards and high explosive filler. Large quantities of high explosive shells will be run through the AIDECS engineering model to provide a data base for future work. The prototype system, to inspect 155MM, M549 shell, will use a linear accelerator radiation source. Preliminary calculations indicate that radiation characteristics of the linear accelerator source are similar to that of the Cobalt 60 radiation source used in the engineering model. The design package for this prototype system has been completed and fabrication has begun. Completion of this system is scheduled for May 1982.



1100 CONTINUOUS FLOW PROCESS

BALL PROPELLANT DBP DETERRENT COATING

1100 CONTINUOUS FLOW PROCESS



This area addresses the range of manufacturing processes that, for the most part, are continuous with minimum human interaction. The Continuous Automated Production of Solvent is illustrated as an example of a continuous flow process.

BALL PROPELLANT DBP DETERRENT COATING

Controlling the penetration of dibutylphthalate (DBP) on the individual grains of propellant is a problem because the process step of deterrent coating has demonstrated significant variability in charge weight from batch to batch. In addition, if there is improper penetration, non-uniform burning is created, which can drastically effect projectile performance.

Previous R&D efforts have identified the mechanism of deterrent coating and established a limited model for predicting the placement of deterrent in the propellant grain. Under a related effort, an overall mathematical model of the deterring process was outlined. Neither model has been demonstrated on production equipment.

The purpose of this project was to join the results of the previous efforts and complete the mathematical model of the deterring operation. The expanded model was to be computer simulated to predict and optimize processing conditions. The resulting conditions were then to be incorporated with a programmable logic control system and both the model and process controller were to be tested at MRC Corp., Hunt Valley, MD.

The FY78 project accomplished the following:

a. Literature Review: This review identified two models for predicting the depth of penetration of DBP in ball propellants.

b. Concept Study: In this phase of the project, experiments established the relationship between agitation speed and the average DBP globule size in a water DBP emulsion.

c. Model Development: An experimental plan was developed to evaluate the effect of temperature and added DBP on the depth of penetration.

d. Control System Procurement: A scope of work was prepared and awarded for the modification of an existing five-gallon reactor and for the improvement of the existing control system so the results could be tested at MRC.

This project was completed in May 1981, with the fabrication, assembly, and inert testing with water of the modified five-gallon reactor and the associated programmable controller. The system was then shipped to ARRADCOM. Acceptance testing which consisted of execution of the time-phased steps required in the propellant hardening phase of manufacture, first with water, then with a mixture of ethyl acetate and water, was completed satisfactorily on 29 May 1981.

APPENDICES

NUMERICAL CONTROL SUMMARY

ROBOTICS SYSTEMS

**DARCOM MINICOMPUTER INTERACTIVE
DESIGN SYSTEMS**

DARCOM MINICOMPUTER NETWORKS

POINTS OF CONTACTS

DISTRIBUTION

APPENDIX A

NUMERICAL CONTROL

NUMERICAL CONTROL (NC)

Numerical Control (NC) is available in eight classes of metalworking equipment owned by the Army. These classes are: boring, drilling, lathes, milling, machining centers, punching, grinding, and forging. The Army inventory of this equipment is shown in Figure 1. Boring machines, lathes, and machining centers make up 79 percent of the inventory, or 563 items. Punching, grinding, and forging machines represent only two percent of the inventory, or 14 items.

Numerically controlled machines make a significant contribution to the production capacity of the industrial base and represent a sizeable investment. The Army numerical control inventory consists of 714 items with an acquisition cost in excess of \$157 million. All but one of these items are controlled by DARCOM. See Figure 1 below for machinery break-out. Government-owned, Government-operated (GOGO) facilities are using 26.5 percent, or 189, of the items and have an additional 7.4 percent, or 53 items, declared idle; i.e., subject to intermittent use, but required to remain in place in support of the current assigned mission. Government-owned, Contractor-operated facilities have 18.6 percent or 133 items, and 28.9 percent, or 206 items, are provided to Contractor-Owned, Contractor-Operated facilities as Government furnished equipment (GFE). The remaining 18.6 percent, or 133 items, are assigned to plant equipment backages (PEP's) for possible use in mobilization production.

NUMERICAL CONTROL INVENTORY BY CLASS

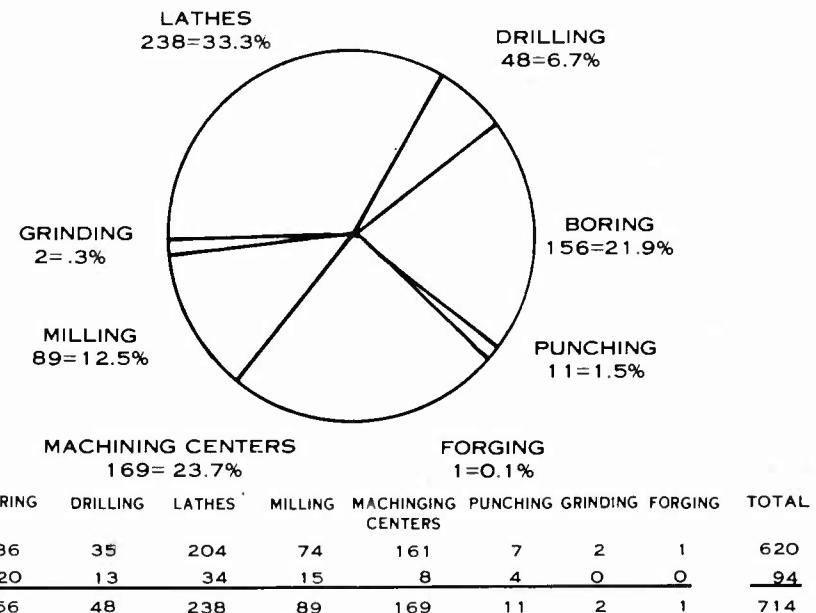


Figure 1

APPENDIX B

ROBOTIC SYSTEMS

ROBOTICS

The Army's industrial facilities at present utilize several levels of automation to achieve its production objectives. Robots are being used in many Army production applications to replace humans in operations which are hazardous and physically taxing. This article will present a few robotic examples to illustrate how they are being applied and will provide a summary of the existing robotic installations.

- o At Chamberlain Manufacturing in Waterloo, Iowa, Unimate Model 2100 robots with special long reach arms are being used in production to remove heated billets from the furnace and place them, properly oriented, into the proper press based on predefined logic and operating conditions.
- o At Norris Industries, robots are used to extract ninety-pound projectiles from material handling Equipment (MHE) and place them into multiple position fixtures on a programmed hoist which carries the shell through the heat treat phases. An application to increase productivity was to employ a robot to remove hot forgings from presses, tip them over to remove flashings and place them on to MHE.
- o Robots are being used at Louisiana AAP and are planned for use at Mississippi AAP for manufacture of the projectile metal parts for the M483. At Louisiana, robots extract forged shells from pressing operations and place them into process carriers in indexed positions for transport to slow cooling operations. The same application is anticipated at Mississippi AAP.

ROBOTIC SYSTEMS

EXISTING

<u>COMPANY/ INSTALLATION</u>	<u>LOCATION</u>	<u>PROJECT NO.</u>	<u>VENDOR</u>	<u>EQUIPMENT</u>	<u>APPLICATION</u>	<u>ACTIVE</u>
Chamberlain Mfg.	Waterloo, IA	5 76 2592 5 77 2592	Unimate	**	Material Handling	Active
Norris, Ind.	Vernon, CA	5 77 3508 5 76 3146	5 Unimate 1 Prab	3) 4000 2) 2000 B 4200	Material Handling	Prove-out
Iowa AAP	Middleton, IA	5 70 2103	Unimate	4000	Material Handling	Inactive
Longhorn AAP	Marshall, TX	5 72 2679	Autoplace	**	Material Handling	Inactive
Louisiana AAP	Shreveport, LA	5 77 2576	4 Prab 2 API	Versatran FA	Material Handling	4 Active
Pine Bluff Arsenal	Pine Bluff, AR	**	Prab	Versatran	Ammunition	Inactive
Rocky Mountain Arsenal	Commerce, CO	**	Prab	Versatran	Material Handling	Inactive
Tooele Army Depot	Tooele, UT	**	Unimate	2000	Demil. Operation	Active

** Not available at time of printing

APPENDIX C

DARCOM MINICOMPUTER

INTERACTIVE DESIGN SYSTEMS

DARCOM MINICOMPUTER NETWORKS

DARCOM MINICOMPUTER INTERACTIVE DESIGN SYSTEMS

EXISTING SYSTEMS

<u>LOCATION</u>	<u>TURNKEY VENDOR</u>	<u>POINT OF CONTACT</u>
ARRADCOM, Aberdeen, MD	Information Displays Inc.	V. Scheno AV 584-2918 (301) 671-3306
ARRADCOM, Dover, NJ	McDonnell Douglas Automation Company	D. O'Connor AV 880-3721 (201) 328-3721
ARRADCOM, Watervliet, NY	Gerber	V. Montuori AV 974-4170 (518) 266-4170
ARRADCOM, Watervliet, NY	Lundy	V. Pascale AV 974-5706 (518) 266-5706
CECOM, Ft. Monmouth, NJ	Information Displays Inc.	John Demko AV 992-2992 (201) 544-2992
CECOM, Ft. Monmouth, NJ	Gerber	John Demko AV 992-2992 (201) 544-2992
DESCOM		
Anniston Army Depot Anniston, AL	Applicon Inc.	Shelly Sewell AV 694-6306 (205) 238-6306
Corpus Christi Army Depot Corpus Christi, TX	McDonnell Douglas Automation Company	F. Gross AV 861-2423 (512) 939-2423
Letterkenny Army Depot Chambersburg, PA	Applicon Inc.	Gerald Cline AV 242-6034 (717) 263-6982
Tobyhanna Army Depot Tobyhanna, PA	Applicon Inc.	Frank Estock AV 795-7099 (717) 894-8301
ERADCOM, Adelphi, MD	Computervision Corp.	H. Hill AV 290-3124 (301) 394-3124
ERADCOM, Adelphi, MD	Computervision Corp.	R. Rosen AV 290-2917 (301) 394-2917
ERADCOM, Adelphi, MD	Hewlett Packard	R. Reams AV 290-3190 (301) 394-3190
ERADCOM, Ft. Monmouth, NJ	Applicon Inc.	R. Reitmeyer AV 995-4769 (201) 544-4769
MICOM, Huntsville, AL	Intergraph	R. Epps AV 746-3524 (617) 653-1000
TACOM	Computervision Corp.	Cliff Sommerville AV 786-8600 (313) 573-8600

DARCOM MINICOMPUTER NETWORKS

<u>LOCATION</u>	<u>VENDOR</u>	<u>POINT OF CONTACT</u>
ARRCOM, Rock Island, IL	PRIME	T. Frandsen AV 793-4701 (309) 794-4701
ERADCOM, Adelphi, MD	PRIME	Dennis Cook AV 290-3110 (301) 394-3110
TACOM, Warren, MI	PRIME	Joseph Ryan AV 786-8167 (313) 573-8167

APPENDIX D

POINTS OF CONTACTS

POINTS OF CONTACT

<u>ARTICLE</u>	<u>CONTACT</u>	<u>AUTOVON</u>	<u>COMMERCIAL</u>
RIA	Steve Robinson	793-5138	(309)794-5138
Watervliet	Charlie Hall	974-5319	(518)266-5319
HICADAM	Bobby Austin	746-2147	(205)876-2147
ECAM	Gordon Little	746-3604	(205)876-3604
Automatic Wave Soldering	Bobby Austin	746-2147	(205)876-2147
FMS	David Pyrce	786-6722	(313)573-6722
Louisiana AAP	Ira Nathan	435-1980	(318)459-5401
Mississippi AAP	Ray Liebelsperger	446-8928	(601)467-8928
Lone Star AAP	Don Dailey	829-1305	(214)838-1305
IGES	Bob Katz	880-3482	(201)328-3482
Pilot Automated Shop Loading and Control System	Scott Macomber	793-6316	(309)794-6316
Foundry Casting Processing	M. Holly	786-5814	(313)573-5814
Gear Die Design & Mfg.	D. Ostberg	786-5814	(313)573-5814
Computer Aided Process	Bobby Austin	746-2147	(205)876-2147
Group Technology of Weapons Systems	CAPT Olson	974-5507	(518)266-5507
Group Technology Requirements Definition	Nathaniel Scott	880-6430	(201)328-6430
Fire Control Mfg Modernization Planning	Nathaniel Scott	880-6430	(201)328-6430
Automatic Control of Plating	Loyd Woodham	746-4948	(205)876-4948
Voice Controlled Computer Programming	Frank Estock	795-7099	(717)894-7099
Layaway of Electronic Process Control System	W. Doremus	328-3084	(201)328-3084
Computer Controlled Press	George Mathes	585-7101	(319)754-7101
Precision Machining of Optical Components	W. Friday	746-8611	(205)876-8611
Computerized Material Properties Development Method for Consolidation & Auto Assy of Small Mines	John Nardone	880-5859	(201)328-5859
Acceptance Criteria of Single Base Propellant	George Mathes	585-7101	(319)754-7101
Stacker Crane	Richard Minert	880-3298	(201)328-3298
Optical Inspection of Printed Circuit Board and Components	G. Silvestro	880-5406	(201)328-3298
Gun Tube Inspection System	Charlie Hall	974-5319	(518)266-5319
Low Cost, High Volume Radiographic Inspection	Robert Brown	746-5742	(205)876-2065
	Paul Rolston	955-3343	(617)923-3343
	B. Parks	746-2065	(205)876-2065

POINTS OF CONTACT (CONT.)

<u>ARTICLE</u>	<u>CONTACT</u>	<u>AUTOVON</u>	<u>COMMERCIAL</u>
Computer-Aided Holographic Composites Inspection	K. Suits	746-5692	(205)876-2065
Automatic X-Ray Inspection System (AXIS)	G. Drucker	880-6264	(201)328-6264
Hot Forging Wall Variation Measurement	Paul Rolston	955-3343	(617)923-3343
Computerized Model Testing Air Defense Missile Fuze	Paul Rolston	955-3343	(617)923-3343
Automatic In-process Microcircuit Evaluation (AIME)	I. Platt	995-2308	(617)923-3343
Automatic Inspection Device for Explosive Charge in Shell (AIDECS)	G. Drucker	880-6264	(201)328-6264
Ball Propellant DBP Coating	J. Goldman	880-2693	(201)328-2693
Ultrasonic Transducer Calibration Equipment	Paul Rolston	955-3343	(617)923-3343

APPENDIX E

DISTRIBUTION

DRXIB-MT

DISTRIBUTION:

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